Discussion Paper

# Expanding the Material Flow Monitor

## A feasibility study on the concepts and data needed to create an integrated measurement system for the circular economy, bio-based economy, eco-taxation and other resource issues

The views expressed in this paper are those of the author(s) and do not necessarily reflect the policies of Statistics Netherlands

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# Abbreviations

## Supply and Use Tables

BP – Basic Prices
PP – Purchaser Prices

MAA – Monetary Asset Account
MST – Monetary Supply Table
MSUT – Monetary Supply and Use Tables
MUT – Monetary Use Table

PAA – Physical Asset Account
PST – Physical Supply Table
PSUT – Physical Supply and Use Tables
PUT – Physical Use Table

VAA – Volume Asset Account
VST – Volume Supply Table
VSUT – Volume Supply and Use Tables
VUT – Volume Use Table

## Other Abbreviations

BBE – Bio Based Economy
CE – Circular Economy
DANK – Digitale Atlas Natuurlijk Kapitaal
DMC – Domestic Material Consumption
MFM – Material Flow Monitor
MFM+ - The Expanded Material Flow Monitor
RME – Raw Material Equivalents
ROW – Rest of World
SEEA – System of Environmental and Economic Accounts
SNA – System of National Accounts
TEEB – The Economic of Ecosystems and Biodiversity
WAVES –Wealth Accounting and Valuation of Ecosystem Services
WEEE - Waste from Electronic and Electrical Appliances

# Executive Summary

*Introduction*

Resources play a vital role in modern society. Materials are used for sustenance, energy, construction, production and are crucial in nearly every aspect of life. Apart from its natural gas reserves, the Netherlands is not resource-rich and is dependent on other regions for most of its resources. In this respect it is similar to many other European countries and Japan which are also net-importers of resources.

It is logical that these countries have developed policies related to the use of resources. The overriding aim is that societies need to become less dependent on resources, both for economic as well as environmental reasons. Global growth in population, affluence, resource scarcity, resources price increases and price volatility are making these resource policies increasingly urgent.

There are however many dimensions to resource issues. Some publications deal with “resource efficiency”, some only on “critical materials”, while others envision a “circular economy” or a “bio based economy”. No wonder that there is a plethora of terms that are used to describe the many perspectives on resource use in society. In many cases the terms refer to separate areas in the debate, but sometimes there is significant overlap.

*This report*

Over the last few years, Statistics Netherlands has published new data on resource flows in Dutch society. Thanks to funding from the ministry of Economic Affairs, the material flow monitor (MFM) was created. The MFM provides data at the national level that shows resource flows for a single year. So far, MFM accounts have been created for 2008 and 2010. The current MFM yields many policy indicators on material intensity, resource dependency, resource use and resource re-use.

The Ministry of Economic Affairs has requested Statistics Netherlands to do a follow-up project. One portion of the project was to create the MFM for 2012 (and to add water use to the accounts). These results will be published in a separate report. The second part of the project was to assess the feasibility of expanding the MFM so that it provides more information for resources policy (the so-called “MFM+”). The results of this second part of the project are provided in this methodological report.

*Results*

The MFM+ should be able to provide information for the many different resource debates. In this report we have focused on the most important perspectives (in the Dutch Policy context) that are related to materials flows, namely: Resource Productivity/Efficiency, Bio based Economy, Ecosystem Accounting/Natural Capital Accounting, Circular Economy, Taxation and Subsidies, Critical and Rare Materials, Urban mining/Metabolism, Waste from Electronic and Electrical Appliances (WEEE) and Planetary Boundaries. Also we look at the spatial scales which are becoming increasingly important: international, national, regional and local.

One strategy would be to create a separate MFM for each of these perspectives. For example, the community that is interested in bio based economy would make use of “MFM+ biobased economy”. There are two reasons why we have not adopted this

approach. Firstly, it would be prohibitively costly to create separate accounts for each debate. A choice would therefore have to be made about which perspectives to facilitate and which not. Secondly, there is a great degree of overlap in the various perspectives. For example, the circular economy concept also attributes great importance to the biotic flows- which is very similar to the idea of a bio based economy. By creating separate accounts for the bio based and circular economy we would not be contributing to an integration of the various perspectives.

For these reasons we present an integrated accounting system that can cater to all perspectives. There are 10 directions in which the MFM could be expanded. We call these “building blocks”:

1. *Assets*
2. *Technology*
3. *Circularity of Residuals*
4. *Biological Dimension*
5. *Economic Importance and Control*
6. *Prices, Taxes and Subsidies*
7. *Quality Labelling*
8. *Eco-Innovation and -Investment*
9. *Business Models*
10. *Spatial Scales (International, National, Regional and Local)*

For each of the building blocks we discuss the methodology, indicators and data availability. The methodological sections show how the current MFM accounts may be expanded, while the indicator sections provide information about what type of policy indicators the MFM+ might provide.

We conclude that in terms of data availability that there are a number of building blocks which we score as “good” in terms of feasibility: *Assets, Economic importance and control. Prices, taxes and subsidies, Spatial Scales and Eco-Innovation and -Investment*. This means that these building blocks are already available or under development. Three buildings blocks are rated “fair” (partially feasible): *Technology, Quality Labelling and Biological Dimension.* For two building blocks our assessment is that extra data would be needed (“poor”): *Circularity of residuals* and *Business models.*

The report goes on to assess a dozen policy questions that the expanded MFM+ would be able to address. It also goes into the various modelling options that would be available if MFM+ data became available.

### *Conclusions and way forward*

This report has shown that the MFM+ provides a useful methodological framework to integrate the insights from many related resource perspectives. As such it provides many useful policy indicators and modelling possibilities to monitor resource policies. Also, the report provides insight into the many Dutch studies/institutes/researchers working on the various resource perspectives. This knowledge base provides a solid foundation to further develop policies and statistics on resource issues. In terms of moving forward we have found that the area of spatial scales seems to be particularly relevant field for future work. Developing the international, national, regional and local statistics helps to link resource problems and solution, which may occur at different spatial scales.

# 1. Introduction

## 1.1 Background

Resources play a vital role in modern society. Materials are used for sustenance, energy, construction, production and are crucial in nearly every aspect of life. Data from Eurostat show that the average European uses around 13.3 tonnes of material resources per capita per year (measured as the Domestic Material Consumption). For the Netherlands the figure is slightly lower, 9.4 tonnes per capita in 2013, but still high compared to the less developed countries.

The pressure on resource use is likely to increase (given growth in global population and affluence) which would lead to increases in prices and price volatility. Unless society's use relationship to resources changes quite soon there may be important environmental and economic consequences. Add to this the fact that European countries have relatively few natural resources, it is logical that governments around the world, and particularly in Europe, are looking at resource use policies.

*International policies and initiatives*

Given these circumstances, individual countries (e.g. DEFRA, 2012; Federal Ministry of Economics and Technology, 2010) as well as the European Commission are developing strategies to secure the supply of vital resources in the future. In 2008 the European Commission launched the 'Raw Materials Initiative' which advocates secure, undisturbed access to natural resources on the world market (European Commission, 2008). Raw materials have been an important part of the European agenda ever since (see European Commission, 2010; 2011b). Key topics include: more efficient use of resources, sustainable production of European extracted resources, increasing the recycling rate, and containing resource prices and their fluctuations. A flagship initiative for a resource efficient Europe was launched within the Europe 2020 strategy, as a more efficient use of resources is the key to securing economic growth and employment in Europe (European Commission, 2011a).

The debate over resources is very diverse. There are many different perspectives on resource issues for which there are countless different labels. Just a few terms that are prevalent in the debate: circular economy, urban mining, resource revolution, bio-based economy, material footprints, eco-taxation, eco-innovation, ecosystem services etc. etc. etc. All these debates answer different resource questions but are also connected because they all deal with society's use of materials.

A couple of influential reports have been published over the last decade or so. The "Resource Revolution" report (McKinsey, 2011) focussed attention on material use, and the reports by the Ellen McArthur Foundation (2012, 2013, 2014 and 2015) (often together with McKinsey) have helped to popularise the concept of the "circular economy". In chapter 2 we will provide a more complete overview of literature in the various resource areas.

*Dutch policies and initiatives*

The Dutch government has also formulated a resource initiative memorandum in order to stimulate national policymaking (Ministry of Economic Affairs, 2011). Its primary target is to secure the sustainable supply of biotic and abiotic natural resources in the future.

There are three ways to accomplish this. Firstly, by substituting resources for alternative resources (e.g. fossil fuels for biomass). Secondly, by increasing the recycling rate. And third, by limiting the demand for resources by increasing resource efficiency.

More recently, the Dutch government has published the "Tussenbalans Groene Groei" ("Mid-term Review - Green Growth"). Many of the themes in this review are directly related to resource management (e.g. "bio based economy", "waste as a resource/circular economy" and the international dimension "trade/aid and investment").

In the Dutch setting many studies have been written to support Dutch resources policy. These were studies on future scarcity and potential policy measures (Wouters and Bol, 2009; PBL, 2011; HCSS, 2009; HCSS et al., 2011), the impact of material use on the environment (CE, 2010), the impact of critical materials on the economy (Statistics Netherlands and TNO, 2010, Basteins et al, 2014; TNO et al, 2015) and the bio-based economy (SER, 2010; Meesters et al, 2013; Kwant et al, 2015). Private companies, such as the Rabobank have also started to look at the concept of the circular economy (Stegeman, 2015).

*Expanding the Material Flow Monitor*

Currently, Statistics Netherlands produces the material flow monitor (MFM) biannually. This is a macro-economic accounting system for materials flows in the Dutch Economy. The MFM is part of System of Environmental Economic accounting (SEEA), which provides a measurement framework connects many of the resource perspectives (circular economy, bio-based economy etc.) in a coherent measurement system.

The current MFM is capable of answering many questions about the resource flows at the national level. However, for some policy issues it will need to be expanded. In this report we have identified ten potential 'building blocks' which could be used to create the expanded MFM (which we will refer to as the 'MFM+'). The aim of this report is to define the conceptual expansion, to suggest potential indicators that might be derived and to assess what data is available to "fill" the building block with actual numbers.

The aim of the report is to explore how the number of policy questions that may be addressed by the MFM can be increased. It also aims to show that many of the resource debates are in fact related, and in some cases overlapping. Note that it was beyond the scope of this study to present empirical work. Our report facilitates future work by providing methodological guidance and information about data availability.

## 1.2 The System of Environmental Economic Accounting (SEEA)

The MFM is an account which is part of the System of Environmental Economic Accounting (SEEA). The SEEA was adopted as an international standard by the United Nations Statistical Commission (UNSC) in 2012 (UN et al, 2014a) and is now being implemented worldwide. In Europe, the production of some of the accounts (including Material Flow Accounts) is legally binding for all EU members.

At the heart of the SEEA is a systems approach to the organisation of environmental and economic information that covers, as completely as possible, the stocks and flows that are relevant to the analysis of environmental and economic issues. In practice, environmental-economic accounting includes the compilation of physical supply and use tables, functional accounts (such as environmental protection expenditure accounts), and asset accounts for natural resources. These accounts are described in section 3.1.

The SEEA applies the accounting concepts, structures, rules and principles of the System of National Accounts (SNA) (UN et al, 2009). This is the measurement system that governs the way that all countries measure their economy. The SNA is a complex set of agreements about how to record the monetary flows in an economy. Similar to the SEEA it is not a single account, but rather a system of interrelated accounts that depict various dimensions of an economy like economic activity, economic growth (GDP) and the general structure of the economy. However also the number of employees per industrial branch is part of the national accounts.

The SEEA is considered a ‘satellite account’ of the national accounts. Consequently, the SEEA allows for the integration of environmental information (often measured in volume or physical terms) with economic information (often measured in monetary terms) in a single framework. The power of the SEEA comes from its capacity to present information in physical and monetary terms in a coherent manner.

In general both the SNA and SEEA accounts present data annually at a meso or macro level for the whole country. At this level a great many research questions can be answered. However, there are some questions, which need a more detailed level of analysis (at the company or process level or at a detailed regional level). In these cases insights from the SEEA can be combined with insights from micro or regional data.

## 1.3 The Material Flow Monitor (MFM)

### 1.3.1 Background

In order to support the Dutch resource policy on the basis of macro-economic data, Statistics Netherlands developed the MFM (CBS, 2013b; Delahaye and Zult, 2013). In this report the MFM for 2008 was presented. Subsequently, the Ministry of Economic Affairs commissioned a second MFM database which covered the year 2010, which became available in 2014 (see annex 2). Currently, work is on-going to compile the monitor for the year 2012 and to revise the 2008 monitor.[1] All this work has been supported by the Ministry of Economic Affairs, which continues a long tradition at Statistics Netherlands in material flows data.[2]

### 1.3.2 Supply and Use Tables

The current MFM is based on the so-called physical supply and use tables (PSUT) which are defined by the SEEA. These accounts measure the supply and use of products/industries. Figure 1.1. provides a simple schematic representation of the monetary and physical supply and use tables (MSUT and PSUT respectively). In the use tables, the columns show which inputs are used in each industry or final demand category. The rows show which categories use the products. The supply table shows the supply of products by industry and imports.

[1] The latter is necessary due to the recent revision of the national accounts. Because the data are based on the monetary national accounts for 2008 data, which needs adjustment to get a consistent time series.

[2] In the early 1990s several ‘material balances’ were produced for the ministry of the environment (see Konijn et al, 1995, 1997). In the period 2000-2003 physical input-output tables were produced for metal and plastics in the context of an NWO PhD project (Hoekstra, 2005).

| **Monetary Supply Table (MST)** | | **Industries** | | | | Import | **Total (BP)** | Taxes&subs.idies | Margins | **Total (PP)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | | | | | |
| **Products and Services** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| **Total** | | | | | | | | | | |

| **Monetary Use Table (MUT)** | | **Industries** | | | | **Final Consumption** | | | | **Total (BP)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | |
| **Products and Services** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| **Value added** | | | | | | | | | | |
| **Total** | | | | | | | | | | |

| **Physical Supply Table (PST)** | | **Industries** | | | | Import | Accumulation | Environment | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | | | | |
| **Products and Services** | Agriculture | | | | | | | | |
| | Mining | | | | | | | | |
| | Industry | | | | | | | | |
| | Services | | | | | | | | |
| **Residuals** | Waste | | | | | | | | |
| | Air emissions | | | | | | | | |
| **Natural resources** | | | | | | | | | |
| **Total** | | | | | | | | | |

| **Physical Use Table (PUT)** | | **Industries** | | | | **Final Consumption** | | | | Accumulation | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | | |
| **Products and Services** | Agriculture | | | | | | | | | | |
| | Mining | | | | | | | | | | |
| | Industry | | | | | | | | | | |
| | Services | | | | | | | | | | |
| **Residuals** | Waste | | | | | | | | | | |
| **Natural resources** | | | | | | | | | | | |
| **Total** | | | | | | | | | | | |

*Figure 1.1. Monetary and physical supply and use table (MSUT and PSUT)*

An important property of supply and use tables is that supply and use for each good and each industry are balanced (i.e. what goes in must come out). Thus, each row and column in the supply table equals the corresponding row and column in the use table.

The current MFM is based on the PSUT and therefore provides information about the physical flows in the Dutch economy. This includes data that is not shown in figure 1.1 such as physical imports/exports per country. Due to the interrelationship with the national accounts a direct link with monetary data (MSUT) is available as well.

An important difference between MSUT and PSUT is that PSUT takes all flows with mass into account. The physical tables show flows of products, residuals and natural resources to and from industrial branches within the economy, households (consumption), the environment and other economies (import and export). The physical use and supply tables are for the largest part derived from the monetary use and supply tables in the national accounts. However, in the national accounts, products are expressed in terms of their monetary value[3] and therefore residuals (e.g. solid waste or $CO_2$ emissions) and natural resources (at the time of extraction) are not part of them. Of course, although residuals and resources have no monetary value, they do have mass, and therefore they are part of a physical system of use and supply tables. Flows without a monetary value are not taken into account in the MSUT. On the other hand, taxes and subsidies are not shown in PSUT, but they do appear in MSUT.

### 1.3.3 MFM Compilation Method

The main data source of the MFM are the monetary supply and use tables of the national accounts. These tables are converted into physical tables by using price information from different sources like the international trade statistics, production statistics and scanner data from super markets. For some commodities, for example energy carriers, physical information is directly available and no conversion of monetary data is required. This procedure provides data on the physical supply and use of all commodities.

The next step involves the addition of material flows that have no monetary value. These are mainly flows between the environment and the economy (e.g. emissions to air and extraction of natural resources) but also flows within the economy like the supply and use of solid waste. Data to estimate these flows are derived from several modules of the environmental accounts and other statistics.

Finally, balancing items are added that reconcile the supply and use for each industrial branch. Some of the balancing items are derived from other variables, like the $O_2$ uptake is estimated on the basis of fossil fuels used for combustion. The loss/gain of water during a production process is only roughly estimated on the basis of available data on water content of products. In some cases the balancing item is a result of the difference between supply and use. This is, for example, the case in the construction industry. Here the balancing item represents the amount (i.e. weight) of buildings and infrastructural works constructed. With all data in place, the supply and use tables need to be balanced. Large differences between supply and use are to be removed after a critical investigation of the data. One of the things to investigate is the relationship between the inputs and the outputs for an industrial branch. For example, for a certain

[3] Note that there are two types of valuation in the monetary supply and use tables. Purchaser prices (denoted with PP in figure 2.1) and Basic prices (BP). This distinction is not very important for this report.

amount of meat produced, the input of a certain number of animals is expected. In the end the small balancing differences are automatically removed by computer software.

As mentioned before the MFM is set up according to international concepts and definitions. This makes it relatively easy to link other relevant statistical data with the MFM. In the last stage of the MFM compilation procedure, data are linked with regard to the stage of production of commodities (raw, semi-final and final), country of origin and destination and raw material equivalent (RME). Also national account data like value added and number of employees are linked.

In Annex 1 the aggregated physical supply and use tables for the year 2010 are presented. For analytical purposes a database is available that contains about 300 products and about 200 industrial branches.

### 1.3.4 MFM Indicators

On the basis of the PSUT tables of the MFM in combination with linked monetary and micro data policy relevant indicators can be derived. These indicators deal with four key themes in the Dutch resource strategy, namely resource efficiency, resource dependency, recycling of materials and environmental impact. Note that for some indicators their reliability in terms of data quality still needs to be proven. At the end of 2015 a MFM time series (2008, 2010 and 2012) will be available. This time series will give an indication of the robustness of the derived indicators:

Indicators for resource efficiency include:

- GDP (Gross Domestic Product) divided by DMC (Domestic Material Consumption)
- Value added per kilogram material use per industry
- Kilogram output per kilogram input per industry
- $CO_2$ intensity ($CO_2$ per unit of output)

Indicators for resource dependency include:

- DMC per unit import per type of material, country of origin of the imports
- Production phase of the imports (raw, semi and final product)
- Imports expressed in raw material equivalents (material footprint)[4]
- Dependency per type of material per industry, substitution of materials

Indicators for recycling include:

- Input of primary materials versus secondary materials per industry

Indicators for environmental impact include:

- $CO_2$ emissions per industry
- Consumption of meat and dairy products by households
- Water use per industry

[4] The RME of a product indicates the amount of raw materials required during the whole production chain. For example the raw materials needed to produce tomatoes include seeds, energy and fertilizer. The RME coefficients were estimated by a research institute (commissioned by Eurostat). They performed a mixed Leontief-LCA calculation, using hybrid Input-Output Tables (HIOTs), to determine the coefficients (IFEU, 2012).

## 1.4 The Expanded Material Flow Monitor (MFM+)

The feasibility study presented in this report, commissioned by the Ministry of Economic Affairs, investigates possibilities to expand the MFM in order to deal with various policy questions. The following research aims are defined:

- *Conceptual framework*: In what way has the accounting system of the material monitor to be expanded to accommodate resource policy questions?
- *Indicators*: Which new indicators might be produced using the MFM+?
- *Feasibility*: Are there enough data available to produce the MFM+?
- *Policy questions*: Which policy questions might be answered using the MFM+ and which analysis/models tools are available?

It is beyond the scope of this paper to provide empirically results for all the direction that are explored for the MFM. Rather it is a feasibility study which explores conceptual and data issues of a MFM+. Although there are no empirical figures, the report does however contain some hypothetical examples to illustrate the conceptual work.

The underlying aim of the report is to provide a blueprint for future expansions of the MFM and to understand the indicators and models that the framework might provide.

Note that in general, the MFM can be expanded in 2 ways:

1. First modules of the environmental accounts can be added to the MFM. Some of these modules might be ready available at Statistics Netherlands, some of these modules are described theoretically in SEEA but are not yet taken into production by Statistics Netherlands. Examples are functional and asset accounts. The asset accounts measure the additions and reductions of stocks of assets.
2. Second is the addition of micro data. A drawback of the MFM-accounting system is that the focus of the measurement is at a national level and companies and products are aggregated into broad classifications. Furthermore, the measurement period is usually a full year (although monetary accounts also have quarterly GDP estimates). These boundaries imply that not all questions on material flows can be answered on a meso/macro level. The analysis will not be useful if: the question is regional rather than national, if the research question involves detailed look at products and industries, or if the questions looks at variations at the daily or monthly level rather annual changes. This is why we have shown the micro and regional data which provide details in these dimensions as well. Of course, the system of national accounts does have a conceptual relationship with the underlying micro data.

## 1.5 Setup of the Report/ Reading guide

### *Setup of the Report*

The report is structured as follows. Chapter 2 describes the various resource perspectives that exist in the literature. Chapter 3 shows ten building blocks (based on the literature review in chapter 2) that may be used to expand the MFM. This section also discusses new indicators that the system might yield and the data availability to produce those modules. Chapter 4 discusses the feasibility, in terms of the data availability. Chapter 5 discusses policy questions that may be addressed using the

expanded MFM. The chapter also discusses which building blocks would be required as well as which models/ that can be used in the policy analysis. Finally, chapter 6 concludes and discusses future steps that might be taken in expanding the material flow monitor.

*Reading guide*

For reader that are more interested in policy questions, and who are less interested in the measurement frameworks, it is possible to skip Chapter 4. Only Chapter 4.1 might be useful as an overview of the 'building blocks' proposed. The chapter on policy question (Chapter 6) contains a discussion about policy questions that might be answered by the MFM+.

## 1.6 Consultations

In May 2015 a number of resource experts were consulted to comment on a draft version of the report.

At the Input-output conference (June 2015, Mexico City) a special session on 'circular economy and physical input-output tables' was organized by Statistics Netherlands. The May-version of the paper was discussed there.

On July 10$^{th}$ 2015 a workshop was held at the Ministry of Economic Affairs. An updated version of the report was discussed with a group of policy makers and researchers.

See annex 1 for details of the experts and meetings. We sincerely thank all participants for feedback during these rounds of feedback.

# 2. Perspectives on Resource Issues

## 2.1 Overview

There is a plethora of literature and policy debates which provide an enormous range of perspectives on resource issues. Each of these perspectives focuses on specific resource areas and problems. Despite the differences, the perspectives also exhibit overlap and similarities.

One of the most striking similarities in the literature is the agreement on the sense of urgency. The publications often start using similar arguments: global population increases and the finite resource stocks that remain make it very likely that society will fundamentally need to change its relationship to resources. A portion of the literature stresses that prices and price volatility already have increased over the last decade and a half, which makes a shift to lower resource use economically attractive. It is also frequently argued that technology, consumer attitudes (e.g. leasing or sharing products) and developments such as urbanisation may help to facilitate the transition as well.

In this chapter we will provide short introductions to some of the most important perspectives on resource issues. These perspectives were deduced from our review of the literature and our discussion with policy makers (notably the ministry of Economic Affairs). The final section will provide a brief discussion of the differences or similarities in the various perspectives. The overview of resources literature will serve as the basis for the expanded MFM presented in chapter 3.

Needless to say, the literature review is not complete. Instead we will focus on the most influential publications and on the debates that are most dominant in the Dutch setting.

## 2.2 Resource Productivity/Efficiency

A first strand of literature on the efficient use of resources focuses on society's challenge to decouple economic growth from material use is the literature on resource productivity (or efficiency). The idea is to use materials more efficiently, in such a way that economic growth can be combined with lower growth of material use (relative decoupling) or even with diminishing material use (absolute decoupling). This strand of work already started in the 1990s with influential reports by the World Resource Institute (Adriaanse et al, 1997; WRI, 2000). These studies helped to launch macro-indicators for material flows such as Total Material Requirements (TMR) and later Domestic Material Consumption (DMC), which are used in the European policies on resource efficiency.[5]

Another influential study that focuses on the efficient use of resources is *Resource Revolution* (McKinsey 2011). The authors argue that, in this time of rapid growth of the world middle class population, a higher resource productivity is necessary in order to avoid (even) more stress on the supply and prices of natural resources, as well as to avoid more pollution and $CO_2$ emissions. They discern a number of ways to reach higher resource productivity. One of them is 'substitution'. This is 'the replacing of costly,

[5] Eurostat has long since started collection of indicators such as DMC and resource efficiency. However, these indicators were also criticised because materials were often solely aggregated according to mass, without giving enough account of their environmental impact. To counter this type of criticism CE-Delft/CML developed a method to weigh material according to environmental impacts (de Bruyn et al., 2004; CE-Delft (2010).

clunky, or scarce materials with less scarce, cheaper and high-performing ones.' One can think of substituting heavier aluminium fuselages by much lighter carbon fibre reinforced plastic airplane fuselages. Another way to reach higher resource productivity is by means of 'dematerialisation'. By optimising product design less material is needed to construct the same product. This has economic and environmental advantages during the production phase, but advantages may well extend throughout the whole lifecycle of the product. For example lighter transport vehicles are generally less energy consuming than heavier vehicles.

## 2.3 Bio based Economy

The literature on the bio based economy (BBE) focuses on the opportunities of using renewable and sustainable resources that have bio based origins. The idea is that substituting biologically derived materials and processes for the production of goods will result in a reduced use of fossil fuels and other non-renewable resources. Following Nowicki et al. (2007) the BBE can be described as an economy 'in which enterprises manufacture non-food products from biomass. Such products include fuel for the transport industry, chemicals, materials, and energy.'

The Dutch Government named BBE as an important part of their policies (Ministry of Economic Affairs 2007). In 2013 it published a protocol on monitoring BBE (see Meesters et al. 2013, Kwant et al, 2015), where it states that ideal of a BBE is mainly about the transition from fossil fuels to a bio based economy (i.e. bio based materials). This coverage of the BBE as proposed by Meesters et al. is shown in the following figure:

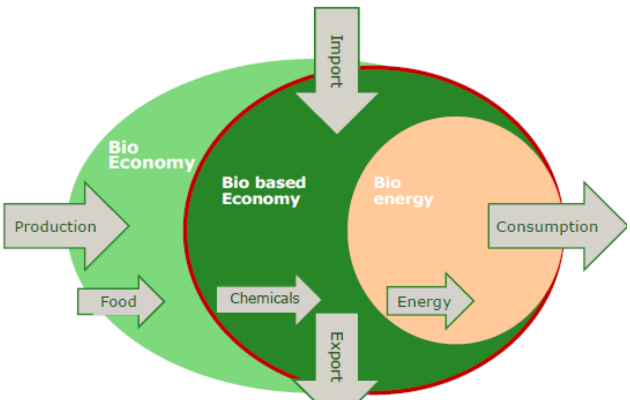



*Figure 2.1. The bio based economy (source: Meesters et al. 2013)*

Figure 2.1 shows that BBE is a part of the bio-economy and that bio-energy is a part of BBE. The BBE contains production and processing chains for renewable vegetable and animal resources[6], which are used for the production of materials chemicals, excipients, fuels and energy.

A first step in measuring the BBE is to discern between biotic and abiotic products. Nowicki et al. (2007, 2008) identified 780 manufactured products that are relevant for measuring the actual and potential size the bio based economy in the Netherlands. A

[6] With the exclusion of the food and the animal feed sector.

second step may involve measuring how biotic products and processes are being used by the industries to produce different types of products each with their own added value. For example, discerning between different types of biorefinery of wheat for different purposes would allow for better estimates of the economic importance of the bio based economy (see Bos et al. 2014).

## 2.4 Ecosystem Accounting/Natural Capital Accounting

Human life benefits in many ways from the ecosystem in which it exists. Such benefits may be called ‘ecosystem services’. In an economic sense, ecosystem services describe the contribution of the ecosystem to the economic system. Examples of ecosystem services include groundwater (provisioning for drinking water or cooling water), forests (regulating the climate by capturing $CO_2$), crop pollination (supporting crop growth) and natural heritage (which has a cultural function) (UN et al. 2014). The stock of useful materials at hand provided by the ecosystem may be called ecosystem capital.

The concept of ecosystem services has a long history (see Daily, 1997; Gómez-Baggethun et al, 2010). At the end of the 1990s a very influential paper was published Constanza et al. (1997) which estimates the total value of ecosystem services to the global economy. Another important study that contributed to the popularity of the concept of ecosystem services is The Millennium Ecosystem Assessment (2005).

The Economics of Ecosystems and Biodiversity (TEEB)[7] draws upon these earlier studies. TEEB is an international initiative to draw attention to the global economic benefits of biodiversity. One of its aims is to establish an objective global standard basis for natural capital accounting. Many of the data collected in this project are collected in the Bank of Natural Capital.[8] Describing ecosystem services and mapping natural capital enables us to explicate the positive and negative impacts of economic activities on natural capital and the ecosystem services themselves.

Another initiative that uses a very similar theoretical background as TEEB is the Wealth Accounting and the Valuation of Ecosystem Services (WAVES) partnership[9] which is an initiative of the World Bank. The World Bank actually has a long history on measuring ecosystem but also natural resources and sustainability in the broadest sense (World Bank, 2006; 2011).

The Dutch Ministry of Infrastructure and Environment (I&M) has commissioned work on the Digitale Atlas Natuurlijk Kapitaal (DANK)[10] which is an outcome of the biodiversity strategy of the EU. The consortium of Dutch institutes which is producing the database is working on GIS based datasets. Despite all the initiatives, conceptual, theoretical and empirical work is still under development.

Ecosystem services and capital are complex and still poorly understood. Nevertheless, efforts to inform decision-makers involve organizing and translating scientific knowledge to economics. Different methods are used for valuing ecosystem services in monetary terms. For instance, one could value the $CO_2$ capturing function of a forest by estimating

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[7] http://www.teebweb.org/

[8] http://bankofnaturalcapital.com/category/natural-capital/

[9] https://www.wavespartnership.org.

[10] http://www.biodiversiteit.nl/nederlandse-overheid-biodiversiteit/biodiversiteitsbeleid-vanaf-2012/hoe-willen-we-de-biodiversiteitsdoelen-bereiken/duurzaam-beheer-van-natuurlijk-kapitaal/meten-en-waarderen-van-natuurlijk-kapitaal/

the replacement costs for a manmade $CO_2$ capturing plant. This would help to valuate one of the regulating functions of the ecosystem in monetary terms. Or hedonic pricing could be used to estimate the added value of a coastal house in comparison of a house with a less spectacular view. This would give an estimate of the monetary value of one of the cultural functions of the local ecosystem.

## 2.5 Circular Economy

In the literature the circular economy is often juxtaposed to the linear economy. The latter is sometimes referred to as 'take-make-dispose' because such an economy extracts resources ('take') to produce products ('make'") which are then thrown away after use ('dispose'). The literature on the circular economy (notably Ellen MacArthur Foundation 2012; 2013; 2014; 2015a,b,c) paints a picture of an economic system in which resources no longer go down this path, but rather cycle in the economy because of repair, reuse, remanufacturing and recycling.

One of the incentives to convert to this system is that companies are beginning to notify their exposure to risk in a linear system (e.g. risks to price volatility and supply distortions). Expectations are that with high growth rates in developing countries, these risks will only increase in the long term due to higher demands of resources. Further, the dispose pattern in the linear economy is seen as the bottleneck for future economic prosperity due to the increasing environmental impact it causes. This raises the urge for a circular economy, which is a system that is restorative and regenerative by intention and design (Ellen MacArthur Foundation, 2012).

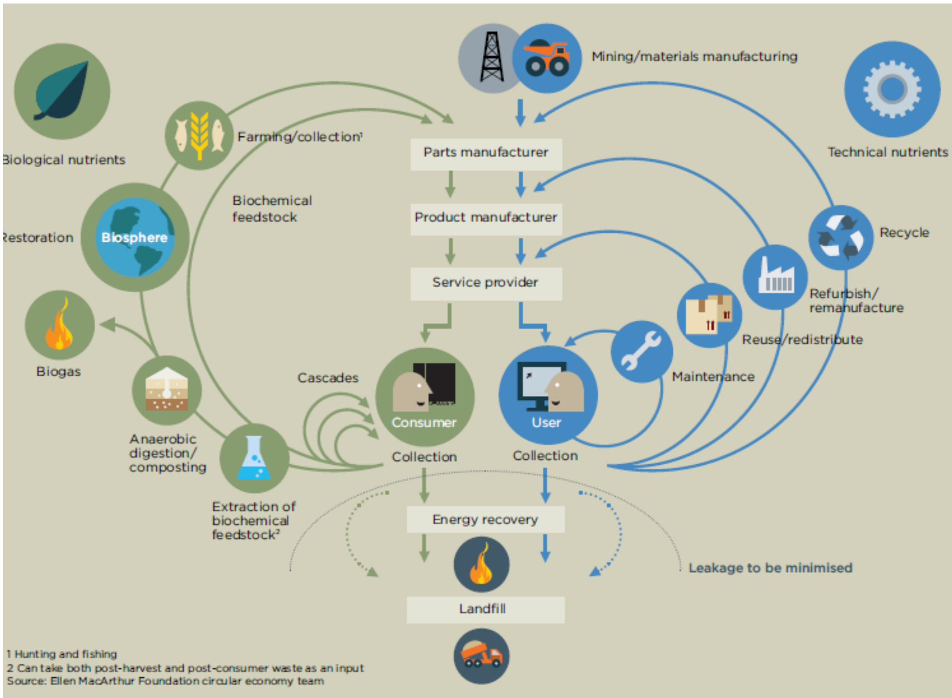



*Figure 2.2. Circular economy (source: MacArthur Foundation).*

Figure 2.2 shows the well-known conceptual framework as proposed by the Ellen MacArthur Foundation. The figure shows that the end-of-life cycle in a linear economy is replaced by so-called feedback loops at the technical nutrients side. These feedback loops include repair, reuse, refurbishment, and recycling.

In terms of quantification, the studies by the McArthur Foundation focus on the economic opportunities of the circular economy rather than on the environmental implications.

TNO published an estimate of the economic and employment potential which the circular economy represents for the Netherlands (Bastein et al, 2013). Based on their model they calculate that the circular economy could yield up to 7.3 billion euro and around 54 000 jobs.

## 2.6 Taxation and Subsidies

Green tax reform (or eco taxes) to measures aimed at reduction of polluting activities via economic incentives. Quite often it is related to the discussion of reducing taxes on labour. By incorporating the environmental impacts of economic activities into prices, eco taxes can directly address the failure of markets to take environmental impacts into account (OECD 2011, p. 1). But there is a tension between raising eco tax revenues on the one hand and the objective of reducing environmental pollution by means of taxation on the other (PBL 2014, p. 4). Emphasizing the first means that decision makers will favour environmental tax bases that are unlikely to 'erode' (inelastic goods), and the opposite is true when environment taxes aim for a green result (ibid.). The lion's share of all green taxation comes from energy products.

Next to the instrument of green taxation, governments stimulates environmental friendly initiatives by means of subsidizing certain activities and products such as solar panels, wind power, electric cars etc. Other economic instruments, besides environmental taxes and subsidies cover emissions permits and environmental liabilities.

An interesting Dutch study on green taxation is the Ex'tax project in which the four big accountants firms (Deloitte, EY, KPMG, PwC) cooperated. The report investigates how 30 billion of tax revenues might be shifted away from labour to environmental issues.[11]

Note that subsidies on products and activities may be detrimental to the environment, which is why they are often referred to as 'harmful subsidies' (PBL 2014:32; van Beers and van den Bergh, 2009). Large environmentally harmful subsidies are specifically found in the energy, transport and agricultural sectors (Drissen et al. 2011). Recently, the Algemene Rekenkamer (2015) published an overview of the subsidies, and the potential impact that they may have on the environment. Discussion about definitions and empirical estimates are on-going.

## 2.7 Critical and Rare Materials

Raw materials for which a higher risk of supply shortage exists, and/or with greater importance for the economy than most other raw materials, can be called 'critical raw materials'. Often this concerns raw materials which are rare. Dependency on critical materials provides economic vulnerability in two ways. Firstly, the supply of critical may be interrupted which might endanger the delivery of the products to market. Secondly, rare resources may be subject to price volatility.

[11] It must be noted that most of the taxes in these types of studies are on energy or emission and waste. There are some issues which make taxes on material flows more problematic. We will discuss these in section 4.7.

For the Netherlands Statistics Netherlands, together with TNO and CML (see CBS 2010) has looked specifically at the risks and problems related to these materials. The European Commission (2010) added the issue of critical materials to its policy agenda as well. In Belgium the RARE³ group (KU Leuven Research Platform focusing on the Advanced Recycling and Reuse of Rare Earths and other Critical Metals) won a Horizon 2020 project in this field (REMAGHIC).

Currently a consortium of TNO, EY, NEVI, HCSS, CML were asked by the ministry of Economic Affairs to analyse the vulnerability of the Dutch economy to critical materials. TNO et al (2015) provides an interim report which described the selection of 64 critical materials. A number of indicators[12] are suggested to assess the supply chains risks involved. The materials will also be linked to the MFM and used to create a database for companies to assess their vulnerability to the supply of these resources.

## 2.8 Urban mining/Metabolism

The process of reclaiming useful materials from products, buildings and landfills is termed urban mining. It also covers the reclamation of rare earth metals from electronics, building materials, polymers et cetera. Urban mining may either lead to the reclamation of (secondary) raw materials, or may be an instrument to prolong the life cycle of certain (parts of) products. A Horizon 2020 project called 'ProSUM –Prospecting secondary raw materials in the urban mine' has been launched to uncover its potential.

In 1965 Abel Wolman introduced term 'urban metabolism'. Today, urban metabolism is understood as a model that describes and analyses the flows of energy and materials arising from socioeconomic urban activities and regional and global biochemical processes. The unit of analysis is typically a city. Urban metabolism aims to provide insights into the behaviour of cities for the purpose of 'advancing effective proposals for a more humane and ecologically responsible future'.[13]

## 2.9 Waste from Electronic and Electrical Appliances (WEEE)

WEEE may be seen as a special case of urban mining. The idea is that many useful materials can be reclaimed from discarded electronic and electrical appliances, especially rare earth metals. Recently, the United Nation University (UNU) has published a number of reports on global e-waste (Baldé et al, 2015a, 2015b), with a focus on environmental, social as well as economic impacts. Sometimes the reclamation of useful materials from e-waste is called e-cycling.[14]

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[12] Geo-economic indicators : Reserve/Production (R/P) ratio and development; Companionality (Measure of the extent to which raw materials are by-products. Geopolitical indicators: Concentration of materials (HHI) of countries origins combined with the stability and quality of governance (e.g, WGI/PPI) of the source countries; existing export restrictions; Regulations on conflict minerals; Price volatility of (raw) materials (MAPII); Ecological footprint (especially water use) of raw materials; Indicators about (expected) regulation with respect to toxicity and health aspect of materials. Performance of the source countries with repscet to ecological and human development (HDI).

[13] See: http://www.urbanmetabolism.org

[14] See http://www.epa.org

## 2.10 Planetary Boundaries

A final concept that is often mentioned in debates about resource use is the concept of 'planetary boundaries'. The concept was introduced by Rockström et al. (2009) to show that there are limits to the carrying capacity of our planet. The authors identify nine planetary boundaries, seven of which were quantifiable: climate change, ocean acidification, stratospheric ozone, biogeochemical nitrogen, global freshwater use, land system change and the rate at which biological diversity is lost. For chemical pollution and atmosphere aerosol loading quantifications still have to be developed. The measurement of the limits is still being refined (Steffen et al, 2015). These planetary boundaries define the 'planetary playing field' for humanity if we want to avoid major human-induced environmental change on a global scale (Rockström et al. 2009). Many of these limits have a clear relationship with materials flows.

## 2.11 Spatial Dimensions

According to some scholars globalisation entered a new phase around 2-3 decades ago. Baldwin (2011) calls this the 'second unbundling' which was brought on by drop in the cost of communications. As a result production processes are increasingly turning into 'global value chains', which implies that the resource use that is embodied in our consumption is also increasingly taking place in other countries.

To study these developments and their impact on the environment, many multiregional input-output databases have been constructed in the last couple of years (for an overview see Tukker and Dietzenbacher, 2013). Some focus more on economic globalisation issues (WIOD, OECD) while others specialize in environmental aspects (Eora, EXIOBASE). The projects have made it possible to calculate footprints and to investigate topics such as carbon leakage. Other topics include water, and analysis of global resource flows (Wiedmann et al, 2013).

Various FP6, FP7 and Horizon 2020 projects have helped to fill the EXIOBASE (de Koning et al., 2009). The most recent Horizon 2020 project (DESIRE) is trying to create a global supply and use table in physical units. A time series is scheduled to be available for the end of 2015.

Apart from the global dimension, there are also efforts to look at resources at a lower spatial scale than at the national level. Regions and cities are developing their own ideas on resource use and the circular economy. Also a number of Horizon 2020 calls focus specifically on the city or regional levels of materials use.

The relationship between the various spatial scales is very important because the problems and solutions related to resource use play at these various scales.

## 2.12 Resource Perspectives and the MFM+

The previous sections described the most important debates on resource issues. It is by no means a complete overview, but it does show that there are sometimes large differences in the questions being asked. At the same time there are similarities and overlap between the various strands of the research.

All the publications considered agree on the point that society needs to change the way in which (natural) resources are used. In some cases the legitimation for this is on

ecological grounds, but often an economic rationale is also used. Many different policy questions are raised in the various debates (we will return to this point in chapter 6).

The aim of the next chapter is to show that all the research questions can be captured in a single, coherent measurement framework. It is therefore not necessary to build a separate measurement systems for each resource question. Chapter 3 presents ten ’building blocks’ to expand the MFM in order to deal with the concepts and debates that were discussed in this chapter.

# 3. Building Blocks to Expand the Material Flow Monitor (MFM+)

## 3.1 Accounting Framework

It would be possible to create a separate accounting structure for each of the resource perspectives discussed in the previous chapter. Data could be created for the circular economy and for the bio based economy and all the other perspectives that were discussed. However it would probably be prohibitively costly to generate create a measurement systems for each. Also this strategy would not take advantage of the overlap that there are in the various concepts.

In this chapter we show that the various perspectives can be measured in a single coherent measurement framework which is based on the Material Flow Monitor (MFM). The framework enables comparisons between the concepts and also to identify efficiencies in terms of collecting data. It may also contribute to more coherence between the various policy discussions.

In this chapter ten 'building blocks'- these are possible directions in which the MFM can be expanded.  Note that sometimes building blocks do overlap. For each building block the methodological aspects are discussed, a number of potential indicators are proposed and data availability is discussed.

*A schematic representation of the resource use in society*

Figure 3.1 provides a schematic representation of resource use in society. This may be seen as a summary of the literature that we discussed in the previous chapter. Each of the ten building blocks is represented in the scheme as well. They are visible as the red outlined and numbered boxes. Let us first look at the scheme before we discuss the ten building blocks.

One of the most fundamental issues at stake in the debates on resource use as discussed in chapter 2 is to improve the efficient use of natural capital assets (shown at the bottom of figure 3.1). On the one hand there are the non-renewable natural assets (fossil fuels, minerals etc.) and on the other there are the renewable (biological) assets that are provided by ecosystems. The long-term goal is to lower the use of the non-renewables significantly, while at the same time using the ecosystems services at levels that do not exceed the natural capacity to regenerate.

The economic cycle (upper part of figure 3.1) in which resources are used consists of three elements: production, consumption and investment (which lead to an increase in economic capital). Producers use the various bulk and critical materials for a variety of reasons (food, technical and energy) to provide commodities to consumers.

Furthermore, the economic system will produce wastes and emissions (right part of figure 3.1). Repair, reuse, remanufacture and recycle help to alleviate our use of resources. Also cascading of biotic materials plays a part here.

Note that production does not translate into companies and consumption is not exclusively households. Governments, companies and households all play a role in production and consumption. The solution to resource use may lie in actions that these actors take individually or through cooperation between the various stakeholders.

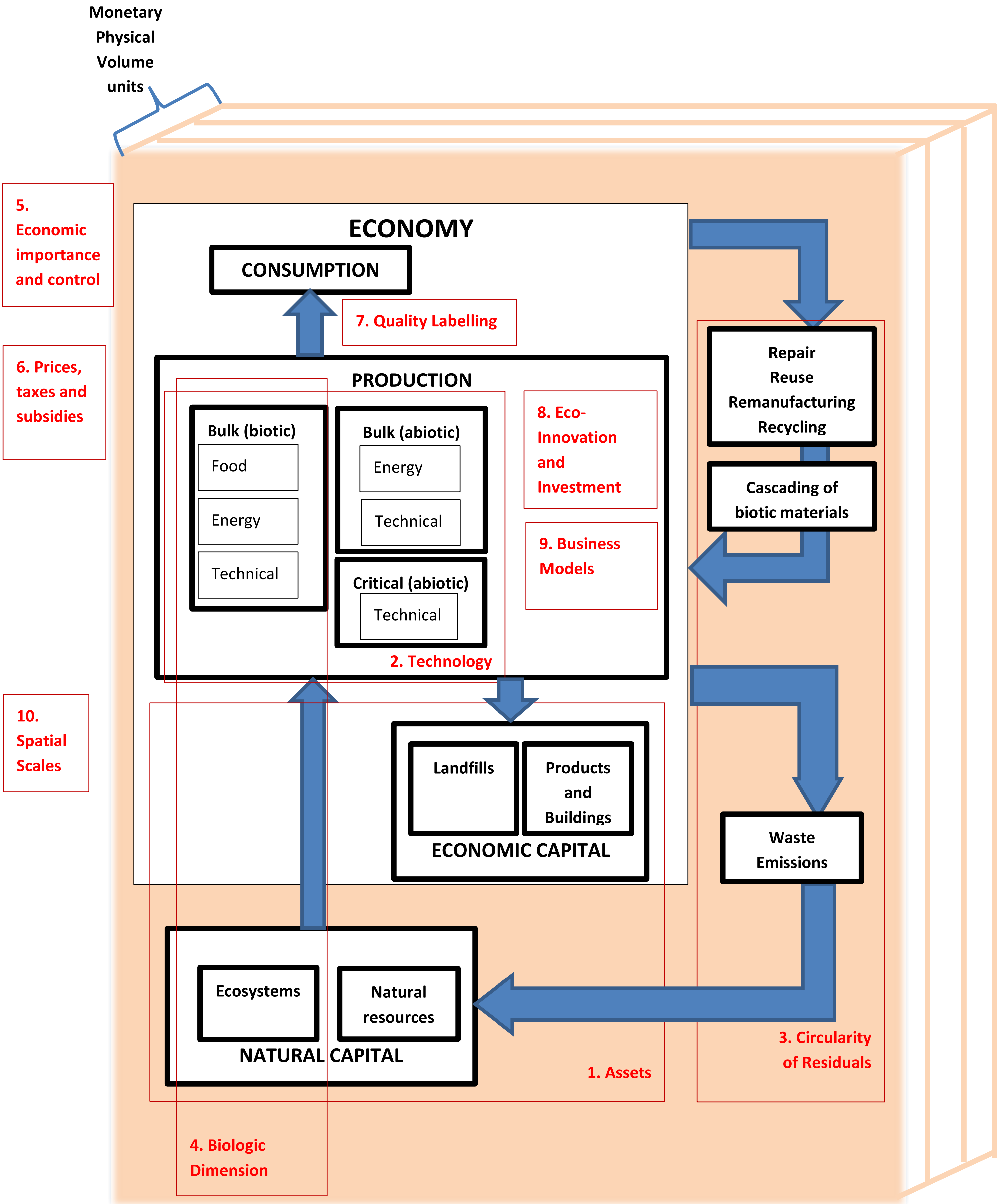



*Figure 3.1. A simple material flows model and the ten building blocks of the MFM+*

The figure shows that there are three units in which the resource economy may be measured: monetary (money), physical (mass) and volume (any other units) terms. We will return to this point in section 3.1.2.

### 3.1.1 Ten building blocks of the MFM+

The overview provided in Figure 3.1. is a very simple model, similar to many frameworks that can be found in environmental economics, the literature reviewed in chapter 3 and the SEEA (which the MFM is part of). The ten building blocks that are distinguished are:

1. ***Assets.*** Many resource policies underline the importance of sustainable use of our natural resources and ecosystems. In order to be able to assess the progression towards sustainability, the natural resource assets and the reduction and additions to their stocks need to be measured (among others). In the monitoring system this can be done by adding asset accounts to the current MFM.
2. ***Technology.*** The efficiency in which resources are used in society, is partly determined by the technology behind production processes and product design. Issues such as material substitution, shifts from abiotic to biotic inputs, or product design are often driven by technology. This building block aims to focus on product processes and product composition in such a way the effects of technological change on resource use can be quantified.
3. ***Circularity of Residuals.*** Society's resource use is also determined by the ability of an economy to prevent the creation of wastes and emissions. The longer the life span of the materials used in an economy, the less natural resources are needed to maintain the same level of material welfare. The life span of products may be extended by repair and reuse, while the life span of components can be extended by remanufacturing. The life span of materials finally, can be extended through recycling. In the discussion of this building block we examine the possibilities to explicate the 'four R's' in the MFM. In the realm of biotic materials the concept of 'cascading' is crucial.
4. ***Biological Dimension.*** Many of the debates on resources use, notably the ones on the bio based and circular economy, pay special attention to the biological dimension of the economy. Partly to understand the provision of ecosystem services (and their economic value) to society, and partly to raise awareness to possibilities of substituting non-renewable technical materials with renewable biological sources. This building block shows what extensions to the current MFM can be made in order to contribute to these debates.
5. ***Economic Importance and Control.*** The building blocks above focus on the physical dimensions of resource use, but many researchers in the field of resource use (try to) make economic quantifications of the importance of various aspects of the resource economy. The question of the ownership ('control') of the companies that use and produce the resources if of interest as well.
6. ***Prices, Taxes and Subsidies.*** Prices of resources and products of course influence consumer and producer behaviour. Governments can influence prices by adopting taxes or paying out subsidies. Data on many taxes and subsidies can already be found in the national accounts.
7. ***Quality Labelling.*** One of the ways in which the consumer may be enticed to buy products that are environmentally beneficial (or less damaging), is by providing sustainability labelling for products or companies. The supply and use

of labelled products can be made visible in the monetary and physical use and supply tables.

8. ***Eco-Innovation and Investment.*** Many companies are innovating and investing in technologies that aim for more ecological or environmentally sustainable production process or products. How these investments can be made visible in the monetary use table is discussed in this building block.
9. ***Business Models.*** In the debate on the circular economy often business models are propagated in which the relation between producer and consumer which provides new ownership options. For example, leasing of products may make it easier for a company to take back its products.
10. ***Spatial Scales.*** The above nine building blocks focus on issue at the national level. However, in our globalized world all of them have an international dimension as well. In this building block we propose different ways of connecting national figures to the rest of the world. We also discuss resources at the sub-national level.

### 3.1.2 The Basic Tables

In order to facilitate the introduction of the conceptual framework of the building blocks we first define the ‘basic tables’. These are the schematic supply, use and asset tables found in Figure 3.2.

Whenever a building block is introduced in the remaining sections, it will be based on these basic tables. We will use the acronyms shows on figure 3.2. and we will denote additions to this basic setup by highlighting in yellow which sections are expanded.

The supply and use tables have already been briefly described in section 1.3. The asset accounts show the opening stock of assets (at the beginning of the year) and then record all the additions and subtractions to them, which provide an estimate for the assets level at the end of the year.

Furthermore the table shows that there are three units (see also figure 3.1). These are separate dimension of the same phenomena. For example cars in an economy may be measured in euros (monetary), kilogram (physical) or in the absolute number of cars (volume).

## MONETARY

| Monetary Supply Table (MST) | | Industries | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Import | **Total (BP)** | Taxes | Margins | **Total (PP)** |
| **Products** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| **Total** | | | | | | | | | | |

| Monetary Use Table (MUT) | | Industries | | | | Final Consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | **Total (BP)** |
| **Products** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| **Value added** | | | | | | | | | | |
| **Total** | | | | | | | | | | |

| Monetary Asset Account (MAA) | | Assets | | |
|---|---|---|---|---|
| | | Economic Capital | Natural Capital | **Total** |
| **Categories** | **Opening stock** | | | |
| | Additions | | | |
| | Reductions | | | |
| | **Closing stock** | | | |

## PHYSICAL

| Physical Supply Table (MST) | | Industries | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Import | Accumulation | Environment | **Total** |
| **Products** | Agriculture | | | | | | | | |
| | Mining | | | | | | | | |
| | Industry | | | | | | | | |
| | Services | | | | | | | | |
| **Residuals** | Waste | | | | | | | | |
| | Air emissions | | | | | | | | |
| **Primary materials** | | | | | | | | | |
| **Total** | | | | | | | | | |

| Physical Use Table (MUT) | | Industries | | | | Final Consumption | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | Accumulation | **Total** |
| **Products** | Agriculture | | | | | | | | | | |
| | Mining | | | | | | | | | | |
| | Industry | | | | | | | | | | |
| | Services | | | | | | | | | | |
| **Residuals** | Waste | | | | | | | | | | |
| **Primary materials** | | | | | | | | | | | |
| **Total** | | | | | | | | | | | |

| Physical Asset Account (MAA) | | Assets | | |
|---|---|---|---|---|
| | | Economic Capital | Natural Capital | **Total** |
| **Categories** | **Opening stock** | | | |
| | Additions | | | |
| | Reductions | | | |
| | **Closing stock** | | | |

## VOLUME

| Volume Supply Table (MST) | | Industries | | | | | |
|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Import | **Total** |
| **Products** | Agriculture | | | | | | |
| | Mining | | | | | | |
| | Industry | | | | | | |
| | Services | | | | | | |

| Volume Use Table (MUT) | | Industries | | | | Final Consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | **Total** |
| **Products** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |

| Volume Asset Account (MAA) | | Assets | | |
|---|---|---|---|---|
| | | Economic Capital | Natural Capital | **Total** |
| **Categories** | **Opening stock** | | | |
| | Additions | | | |
| | Reductions | | | |
| | **Closing stock** | | | |

*Figure 3.2. The Basic Supply & Use Tables and Asset Accounts*

## 3.2 Building Block: Assets

### 3.2.1 Conceptual Framework

Many resource debates are driven by the aim to manage natural resources in such a way that the use of non-renewables can be reduced and the use of biological resources does not exceed the regenerative process of nature. Inclusion of the asset accounts of natural capital (ecological assets) is therefore crucial.

Currently the Dutch MFM framework focuses on physical supply and use tables (see section 1.3) and does not include full asset accounts yet. More comprehensive tables on natural resources could be added easily (see section on data availability). A sketch of the conceptual setup of the asset accounts is presented below.

*Natural resources*

Figure 3.3 shows a stylized representation of the asset accounts as recommended by the Central Framework of the SEEA (UN et al., 2014a). It is a combination of the table 2.3 (ibid., p. 19) and table 5.2.1 (ibid., p. 125) of the SEEA. The rows show the various types of additions and subtractions, while the columns show natural resource types.

| | | 1 Mineral and energy resources | | | | | 2 Land | 3 Soil resources | 4 Timber resources | | 5 Aquatic resources | | 6 Other biological resources [c] | 7 Water resources | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.1 Oil resources | 1.2 Natural gas resources | 1.3 Coal and peat resources | 1.4 Non-metallic mineral resources [b] | 1.5 Metallic mineral resources | | | 4.1 Cultivated timber resources | 4.2 Natural timber resources | 5.1 Cultivated aquatic resources | 5.2 Natural aquatic resources | | 7.1 Surface water | 7.2 Groundwater | 7.3 Soil water |
| Opening stock of environmental assets | | | | | | | | | | | | | | | | |
| Additions to stock | Growth in stock | | | | | | | | | | | | | | | |
| | Discoveries of new stock | | | | | | | | | | | | | | | |
| | Upward reappraisals | | | | | | | | | | | | | | | |
| | Reclassifications | | | | | | | | | | | | | | | |
| Reductions of stock | Extractions | | | | | | | | | | | | | | | |
| | Normal loss of stock | | | | | | | | | | | | | | | |
| | Catastrophic losses | | | | | | | | | | | | | | | |
| | Downward reappraisals | | | | | | | | | | | | | | | |
| | Reclassifications | | | | | | | | | | | | | | | |
| Revaluation of the stock[a] | | | | | | | | | | | | | | | | |
| Closing stock of environmental assets | | | | | | | | | | | | | | | | |

*Figure 3.3. SEEA-Central Framework asset account*

[a] Only applicable for asset accounts in monetary terms.

[b.] Excluding coal and peat resources

[c.] Excluding timber resources and aquatic resources

*Ecosystems Accounts*

The SEEA-Central Framework asset account measures the environmental assets (or natural resources). However, society's reliance on nature goes further than just these non-renewable resources. Therefore a report called SEEA Experimental Ecosystem Accounting (UN et al, 2014b) has been prepared which also includes assets like land and ecosystems. However, the discussion about the definitions and classifications of these assets is still on-going. Currently, technical guidance documents are being prepared by the SEEA EEA forum of experts under auspices of the UN Statistical Division. See section 3.5 for more information on the ecosystem services which are provided by these assets.

*Urban mining*

It is not only the stocks of natural capital that are of interest. There is a considerable stock of resources embodied in economic assets (buildings, durable products (such as cars) and landfills). This is why they are sometimes referred to as urban mines'. These assets can be measured in monetary, physical and volume terms.

*International dimension*

The asset account shows the natural capital within a particular country. However, because of imports, a large portion of the resources may come from abroad. On the other hand, many of the domestic resources may end up in our exports. Therefore, a description of national assets becomes more relevant when they can be related to global asset accounts. We will discuss the international dimension separately in section 3.11 (including the calculations of Raw Material Equivalents (RME)).

### 3.2.2 Potential Indicators

The indicators for *natural resources* would provide information about the quantity of remaining assets, their economic value and the rate of depletion. Natural gas and crude oil are already part of the environmental accounts and could easily be added to the MFM. Other assets would be new to the MFM-framework:

- Stock of natural resources remaining in physical or volume units
- The economic value of the stock of natural assets
- Depletion rate
- Asset life

*Ecosystems asset accounts* could provide information about the economic and physical dimensions of the ecosystems assets and land. Examples include:

- Monetary value and or volume units (number and quantity of species) of ecosystem assets
- Land area under organic farming
- Relative percentage build-up areas of total area

The *urban mining* indicators could focus on the potential resources that are embodied in landfills, buildings and durable products:

- Potential materials in products, buildings and landfills

Both the indicators belonging to the ecosystem asset accounts and to urban mining would be new to the MFM-framework.

*Combining physical and volume asset accounts*

A combination of information in physical and volume units may also lead to more insights. Below in example 3.1 we show how information from asset accounts in physical and volume units may help to show how the stock of cars become lighter and more fuel efficient. This may lead to a whole range of indicators that can relate the existing stock to the new stock of cars.

- Average $CO_2$ emissions per kilogram from new passenger cars
- Amount of metal embodied in the stock of cars

*Example 3.1. Hypothetical example of an assets account for cars*

| | PAA | | PAA/VAA | | VAA | | |
|---|---|---|---|---|---|---|---|
| | tons | of which metal | Weight of cars | of which metal | Number of cars | Fuel efficiency | Average age |
| Opening Stock | 500000 | 475000 | 1000 | 95% | 500 | 15,0 | 7,0 |
| -New cars added | 45000 | 37500 | 900 | 83% | 50 | 20,0 | 0,5 |
| -Old cars removed | 27500 | 26125 | 1100 | 95% | 25 | 10,0 | 15,0 |
| Closing stock | 517500 | 486375 | 986 | 94% | 525 | 15,7 | 6,0 |

## 3.2.3 Data Availability

*Natural resources*

*Mineral and energy resources*

The Netherlands have large quantities of natural gas and a smaller amount of oil. Statistics Netherlands already publishes asset accounts for these two fossil fuels every year in the Environmental Accounts publication (CBS, 2014). The source data are taken from annual data published by TNO and Ministry of Economic Affairs (1988–2014). Annex 3 shows the natural gas assets accounts which were published in 2014 (CBS, 2014). For non-metallic mineral resources (e.g. sand, salt) there is not enough data at hand in order to estimate physical assets. The Netherlands do not possess any metallic mineral resources, nor coal or peat resources.

*Timber resources*

It is possible to make physical asset accounts on timber resources (both natural and cultivated), using data available from PROBOS and ecosystem accounts. It is not sure if monetary asset accounts can be made. Internationally, there are methods available to monetize physical assets, but their application in the Dutch context must be examined.

*Aquatic resources*

In principle it is possible to compile physical natural aquatic accounts. Estimates for the amount of fish and other aquatic resources would require many assumptions. With regard to the monetary value of aquatic resources, there are methods developed in order to monetize physical assets, but their application in the Dutch context has to be examined yet. Cultivated aquatic assets (e.g. farmed fish) are treated the same as livestock in the national accounts.

*Water*

Statistics Netherlands is able to compose asset accounts for surface water and soil water. This includes a time-series. For ground water it is much harder and not directly possible. As of yet no (historical) information on ground water exists. It is not common to value water in monetary terms (see Edens and van Leeuwen, 2013).

*Ecosystems accounts*

There is currently a project being carried out by Statistics Netherlands, funded by the Ministry of Economic Affairs to set up ecosystem accounts for the Netherlands. This will be done in close cooperation with the University of Wageningen. The project makes use of the Digitale Atlas Natuurlijk Kapitaal (DANK) which is also currently being developed. DANK is a GIS database which combines regional data from various sources (Alterra, RIVM, Deltares, LEI, RWS, BIJ12, DLG, Ministry of Infrastructure and Environment (STRONG), INSPIRE and Statistics Netherlands). It is not yet clear whether the project will focus on ecosystem services (see section 4.5) or will also include the assets accounts.

*Planetary boundaries*

The work on planetary boundaries is still largely experimental. There are some 'control indicators' that are identified for the 9 planetary boundaries by the Stockholm Resilience Centre. These may be taken as a starting point for further development of this rserach area.

*Urban mining*

Several international projects are looking at the potential resources that are embodied in buildings, products and landfills.

The United Nations University recently published a number of important studies in the specific area of e-waste (Baldé, 2015a,b and Wang, 2014). This group will publish a report for the European Commission shortly as well. This body of work contains details information about 54 types of electrical and electronic equipment, including average weight, life span, and total stock. The data, as well as the methods, in this body of work are very promising. For more information about product characteristics see also the data availability in section 3.3.[15]

A new Horizon 2020 project 'ProSUM – Prospecting secondary raw materials in the urban mine and mining waste' is continuous and expands the work of e-waste group It will produce the "EU Urban Mine Knowledge Data Platform (EU-UMKDP) providing user friendly, seamless access to data and intelligence on mineral resources from extraction to end of life products with the ability to reference all spatial and non-spatial data."[16]

Statistics Netherlands estimates the potential valuable metals and phosphor which can be recovered from waste water slush. 50 companies have been approached to see what type of information they have.

The asset accounts on urban mining could give rough estimates for the Netherlands as a whole. When the physical data are available, monetary estimates can be made as well.

[15] Statistics Netherlands also participates in another project on e-waste (Huisman et al, 2012).

[16] http://www.weee-forum.org/prosum-0

## 3.3 Building Block: Technology

### 3.3.1 Conceptual Framework

Technological development plays a vital role in the discussion about resources. It is an important driver of processes of dematerialisation and substitution. There are various dimensions to technology which all play a part:

1. *Production process*. The way in which goods and services are produced has a direct impact on which resources will be utilized. Technology driven changes in production process may lead to substitution, dematerialisation, prolonged lifespan of the product or less waste during the production process and therefore may lead to a lower resource use.
2. *Product composition*. The design of the product determines what materials are used. When the products composition, i.e. the materials of which the product is composed of, can be improved with regard to resource use, redesigning may lead to the use of lighter materials or may help to shift from biotic to abiotic materials.
3. *Other product characteristics*. There are many aspects of the product characteristics, besides the product composition or the production process, that determine the environmental pressure that a product exerts on society. One could think of the energy efficiency, longevity, technical recyclability or a host of other characteristics. Technological advances can help to minimize this exerted pressure.

The first two technological aspects can be produced by adjusting the physical use table (PUT) in two ways. The issues mentioned before as 'other product characteristics' can be registered mostly in the VST and VUT.

- It is possible to split the production process into two parts (see figure 4.4): "use for transformation" and 'final use' (Konijn et al, 1997; Hoekstra, 2005, 2006). These categories reflect the role that the resources play in the production process. In case of 'use for transformation', the resources end up in the product. In the case of 'final use', the resource is used for other purposes. For example, fossil fuels are used in production processes, but their role is not to become a component of the product. By adjusting the PST in this way, certain changes in the production process can be tracked.
- A third dimension, which shows the material composition of the products can be added to the use table (see figure 3.4-note that the supply tables could also be made 3 dimensional). The extra dimension enables us to introduce more technical knowledge product composition in the MFM. Long term changes in product composition indicates substitution through changes in product design. If one of the materials is a critical material then that can be specified, to specify the vulnerability to supply shocks. A split might also be made between biotic versus abiotic or virgin versus circular.

| Physical Supply Table (PST) | | Industries | | | | Import | **Total** |
|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | | |
| **Products** | Agriculture | | | | | | |
| | Mining | | | | | | |
| | Industry | | | | | | |
| | Services | | | | | | |
| **Residuals** | Waste | | | | | | |
| | Air emissions | | | | | | |
| **Total** | | | | | | | |

| Physical Use Table (PUT) | | Industries | | | | | | | | Final Consumption | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Use for transformation | | | | Final use | | | | | | | | |
| | | Agriculture | Mining | Industry | Services | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | |
| **Products** | Agriculture | | | | | | | | | | | | | |
| | Mining | | | | | | | | | | | | | |
| | Industry | | | | | | | | | | | | | |
| | Services | | | | | | | | | | | | | |
| **Residuals** | Waste | | | | | | | | | | | | | |
| **Primary materials** | | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | |

Material 3
Material 2
Material 1

*Figure 3.4 Building block: Technology*

## 3.3.2 Potential Indicators

*Numerical example*

The third dimension of the PUT is probably best illustrated using an example. Example 3.2a and 3.2b show a hypothetical situation that illustrates product composition, dematerialisation and substitution. The third dimension of the use table is represented by two separate use tables: the first one records metal content while the second one shows plastics. In this way not only the mass of upholstery, bodywork and cars can be presented, but the product composition of the parts as well. For example, the 100 tons of upholstery used for bodyworks composes of 50 tons of metal and 50 tons of plastic.

| **Physical Supply Table (PST)** | | **Industries** | | | | **Industries** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Car Ind. | Services | Agriculture | Mining | Car Ind. | Services | Import | **Total** |
| **Products** | Natural Gas | | | | | | | | | | |
| | Upholstery | | | | | | | | | | |
| | Bodywork | | | | | | | | | | |
| | Cars | | | 1000 | | | | | | | 1000 |
| **Residuals** | Metal waste | | | | | | | | | | |
| | Plastic waste | | | | | | | | | | |
| | $CO_2$ | | | | | | | 300 | | | |
| **Total** | | | | **1000** | | | | **300** | | | |

| **Physical Use Table (PUT)** | | **Industries** | | | | | | | | **Final Consumption** | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Use for transformation** | | | | **Final use** | | | | | | | | |
| | | Agriculture | Mining | Car Ind. | Services | Agriculture | Mining | Car Ind. | Services | Export | Government | Consumers | Investments | |
| **Products** | Natural Gas | | | | | | | 200 | | | | | | |
| | Upholstery | | | 100 | | | | | | | | | | 100 |
| | Bodywork | | | 900 | | | | | | | | | | 900 |
| | Cars | | | | | | | | | 600 | | 400 | | 1000 |
| **Residuals** | Waste | | | | | | | | | | | | | |
| **Primary materials** | Oxygen | | | | | | | 100 | | | | | | |
| **Total** | | | | **1000** | | | | **300** | | | | | | |

| **Physical Use Table (PUT) for metal** | | **Industries** | | | | | | | | **Final Consumption** | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Use for transformation** | | | | **Final use** | | | | | | | | |
| **Products** | Natural Gas | | | | | | | | | | | | | |
| | Upholstery | | | 50 | | | | | | | | | | 50 |
| | Bodywork | | | 900 | | | | | | | | | | 900 |
| | Cars | | | | | | | | | 570 | | 380 | | 950 |
| **Residuals** | Waste | | | | | | | | | | | | | |
| **Primary materials** | Oxygen | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | |

| **Physical Use Table (PUT) for plastics** | | **Industries** | | | | | | | | **Final Consumption** | | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Use for transformation** | | | | **Final use** | | | | | | | | |
| **Products** | Natural Gas | | | | | | | | | | | | | |
| | Upholstery | | | 50 | | | | | | | | | | 50 |
| | Bodywork | | | | | | | | | | | | | |
| | Cars | | | | | | | | | 30 | | 20 | | 50 |
| **Residuals** | Waste | | | | | | | | | | | | | |
| **Primary materials** | Oxygen | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | |

*Example 3.2a Example of Building block: Technology*

| Indicators | |
| --- | --- |
| Share of metal in upholstery | 50% |
| Share of metal in bodywork | 100% |
| Share of metal in cars | 95% |
| Weight of cars (kg) | 1000 |

*Example 3.2b Indicators from the Example of Building block: Technology*

In example 3.2b a number of indicators are shown. If we had data for multiple years we could see the changes in product composition (i.e. substitution) and the change of the weight of the car (i.e. de-materialisation). Note that the latter information would also need information from the VSUT.

*Other indicators*

Apart from the hypothetical example, there are many other indicators that may be derived from this module. Examples, of the indicators that are related to the production process include:

- Share of various energy sources and resources in production
- Resources used for final use in the production process, using the 3d-PSUT and the distinction between use for transformation and use for final use. This is an alternative for using RME's (which is already part of the current MFM).

Indicators for product composition might show, as the numerical example shows, the material content of products (and changes therein):

- Material composition per product. Note that this is different to RME because RME show the generated material use in the whole production chain but not necessarily physically embodied in the product.

The indicators for 'other product characteristics' could cover a multitude of aspects that influence the environmental impacts during its life cycle:

- Technical life span
- Actual life span
- Energy and $CO_2$ efficiency (already available in MFM)
- Product Weight
- Technical recyclability
- Life cycle analysis (LCA) indicators

### 3.3.3 Data Availability

*Production process*

The MST and MUT of the national accounts provide a monetary estimate of the inputs that are used in the production process.

There is a no national database on production processes and the information that may be used by this would therefore have to be collected. Alternatively assumptions or data that are related to this topic could be exploited.

*Product composition*

Some data on product composition is readily available. However, the translation of this data to product groups of the national accounts is not straightforward. The product groups of the national account are not homogeneous, especially not the ones

concerning electronics. Furthermore, the products within one product group may change in their product composition depending on the industry in which they are produced.

Nevertheless, TNO has databases and there are estimations on raw material equivalents (RME) that offer some information about product composition of product groups within the national accounts. Therefore, to connect the TNO-database and RME-data could offer some useful insights.

Note that that a complication in creating a third dimension in figure 3.4 is that many of the industries produce more than one product (so-called by-products). All the inputs have to be assigned to one of the outputs. This requires a significant degree of technical knowledge.

In the UNU e-waste projects (Baldé, 2015a,b; Wang, 2014) have gathered information about the material content electronic products categories. Wang (2014, p73-73 ) list the common metals (Fe, Cu, Al), plastics and 'other'" for many electrical and electronic appliances.

It is not yet clear whether databases on life-cycle assessment (LCA) such as ECOINVENT will be able to provide this type of information. A CBS study, in commission of Eurostat, showed that linking information from ECO-INVENT to the classification of the MFM and to country specific production processes was not straight forward (Li and Delahaye, 2013).

*Critical materials*

Apart from the common metals and plastic, Wang (2014, p73-74) also list the material content of three precious metals (Au, Ag and Pd).

Rietveld et al. (2013) use a global MFA method, by using data on extraction, trade and waste/recycling an estimate has been made of the content (comprising of 5 elements REO, Ag, Co, In, Ga) of 420 products (Rietveld et al., 2013).

In Bastein et al. (2014) the use of 22 critical materials are related to the industries and products. The underlying database can already be linked with the MFM. In a new project, funded by the ministry of economic affairs, the list has been expanded to 64 additional abiotic materials (TNO et al, 2015). A website based tool will make this database available for businesses and the public in general.

*Product characteristics*

Other product characteristics that may be relevant from an environmental perspective may come from all sorts of sources. Life cycle inventories may be used, labelling information (for example on energy use and $CO_2$ emissions).

Aspects such as product life span might be found for groups of products. For example, Baldé et al (2015b) produced estimates of Lifespan distribution and product weight in Annex 2 and 3 respectively.

With respect to cars, Statistics Netherlands publishes data on the age, weight, average emission and type of cars.[17] The age of car wrecks is also recorded in the 'Compendium voor de Leefomgeving'.[18]

[17] http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=71405NED&D1=32-53&D2=13-131&D3=l&HDR=G1,G2&STB=T&VW=T

[18] http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0135-Aantal-voertuigwrakken.html?i=1-4

## 3.4 Building Block: Circularity of Residuals

### 3.4.1 Conceptual Framework

As depicted in figure 3.3, this building block deals with the circularity of resources and the eventual emission of waste and emissions place from an economy. We also include in this section the mechanisms identified by the Ellen McArthur foundation which enhance the circularity of the system (repair, reuse, remanufacturing and recycling, in short 'the four R's').

Residuals and emissions that flow to the environment are already part of the current MFM and they therefore do not pose any significant conceptual challenges. However, the four R's aspects are interesting from a conceptual perspective. Each of these has a physical and monetary dimension, but they have differences in terms of their impact on resource flows and ownership.

Flows of residuals between the economy and the environment consist only of $CO_2$ in the current Dutch MFM. Note that wastes that are taken to a landfill are considered flows within the economy. However, other modules from the environmental accounts, such as emissions to water and emissions to air of greenhouse gasses, can easily be added to the MFM. Also covered in the current MFM is the recycling of waste and secondary materials. Notice that recycling within a company is not covered in the accounts.

Not directly covered in the current MFM are repair, reuse and remanufacturing. From a physical perspective reuse, repair and remanufacturing are aimed at lengthening the life span of products or their embodied materials. Together with recycling, all these processes lead to lower use of virgin materials.

There exists a hierarchical or 'cascading' relationship between the four R's. In the case of reuse all the knowledge, labour and material that is embodied in the product is preserved. In the case of repair or remanufacture the knowledge, labour and material (or material composition) is partially lost. In case of recycling an even bigger share of the knowledge and labour and material composition of the product at hand is lost.

The issue of ownership is very important in national accounting and therefore in the MFM. In the case of remanufacturing and recycling, the product is no longer owned by the consumer because the product has been discarded (or sold). In the case of reuse, the product is transferred from one consumer to the other. Finally, in the case of repair, there is no transfer of ownership.

The difference in ownership means that all of the four R's are recorded differently in the monetary accounts (supply and use tables). In the case of repair, this is a service that is provided and which is part of the monetary supply and use tables of the national accounts. As services do not have a physical dimension they do not appear in the MFM. For reuse, it is only 'production' if a company has facilitated the reuse. For example, if a second hand shop sells (trades) a bicycle and the margin is considered production. However, the value of the product, i.e. the value of the second-hand bicycle, is not production. Similar to 'repair', trade margins do not have a physical dimension and are therefore not part of the 'physical' accounts. If reuse takes place as a result of a transaction between consumers (households) these flows are recorded in neither the physical nor the monetary accounts.

Remanufacturing and recycling contribute to production because through the collection of residuals there is contribution to value added. If residuals (waste) do not have a monetary value they are only part of the physical accounts but not the monetary accounts.

### 3.4.2 Potential Indicators

There are many indicators that may be produced using this building block. They include indicators for the total waste generated as well as the treatment methods or the shares of the four R's.

Indicators that can already be derived from the current MFM are:

- Generation of waste (kg)
- Treatment method (incineration, landfill or recycling) of waste (kg)
- Use of secondary material versus use of primary materials per sector[19]

Indicators that can be derived if the MFM is extended with data on repair, reuse and remanufacturing are:

- Prevalence of economic activities that relate to repair, reuse or remanufacturing (e.g. value added, employment)
- Amount of materials that are being repaired, reused or remanufactured (kg)

In addition it would be very interesting to have an indicator that measures the difficulty in recycling:

- Purity of the residual stream
- Higher or lower cascading of recycling
- Recycling of scarce materials in e-waste
- Averages for treatment/collection costs stock and/or flow

### 3.4.3 Data Availability

In order to extent the current MFM as described above the following potential data sources are available.

*Waste and emissions*

The Environmental accounts/MFM already includes information about wastes and emissions.

*Repair*

The MST and MUT of the national accounts have information about the repair of cars, computers, furniture and 'other'. This monetary data offer an indication, but there is very little information about the physical dimension of repaired products.

*Reuse*

The MST and MUT include information about the sales and export of used cars, trucks and machines. It is hard to get a full view on reuse in the economy. Some transactions of goods between consumers (for example through websites or gifts) can perhaps be derived from websites and mobile apps (e.g. marktplaats.nl). In the near future transactions between consumers, especially via web services, will obtain high priority for Statistics Netherlands. This means that data availability is projected to become better.

*Remanufacturing*

There is no specific information about remanufacturing in the national accounts. This would require additional data acquisition from companies on their use of old parts in new products.

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[19] Note that data on the use of secondary products is for some occasions very weak and needs improvement.

*Recycling*

Statistics Netherlands is currently carrying out a project that aims to compile an indicator that measures the use of secondary raw materials with respect to raw material inputs. The used methodology is suggested by Eurostat and uses only data that is already available from other statistics. However, in order to obtain better data on secondary material use, it is recommended to gather additional information from companies in the future.

*Purity of waste*

There are no sources that indicate the purity of wastes although the McArthur Foundation (2014) and other reports identify this as an important aspect which determines the recyclability of waste.

*Cascading in biotic materials*

It is not clear what an indicator of different levels of cascading would look like. Therefore data availability is also not clear.

*Rare materials in e-waste*

Currently UNU in cooperation with Statistics Netherlands is conducting research on the amount of Rare materials in e-waste. It might be possible to link the results of this study with the accounting framework applied in the MFM.

## 3.5 Building Block: Biological Dimension

### 3.5.1 Conceptual Framework

Many of the debates, notably the bio based and circular economy discussions, pay special attention to the biological dimension of the economy. In part to understand the provision of ecosystem services (and their economic value) to society, and in part to raise awareness to possibilities of substituting non-renewable technical materials with renewable biological sources. Figure 3.5 shows how these two aspects may be represented in an accounting setting.

The contribution of the ecosystem services can be added to the production accounts (for the ecosystem *asset* accounts see section 3.2). A producing sector 'environment' is added to the supply table (to the monetary, physical and volume variants)[20]. In addition the rows for provisioning, regulating and cultural services are added to both the supply and use tables. Note that of these three types of services only the provisioning services is likely to have a physical dimension. This may include the provision of wood, fish and other biological resources.

[20] There is no need for an ecology column in the use table, because there is no reason to ascribe a monetary value to the additions from the economy to the ecosystem, i.e. residuals. Note that in the PSUT and VSUT at least some of the additions from the economy to the ecosystem are shown in the form of waste and emissions.

| Supply table (Monetary, Physical and Volume) | | Industries | | | | Import | Ecosystem | Total |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | | | |
| Products | Agriculture | | | | | | | |
| | Mining | | | | | | | |
| | Industry | | | | | | | |
| | Services | | | | | | | |
| Ecosystem services | Provisioning | | | | | | | |
| | Regulating | | | | | | | |
| | Cultural | | | | | | | |
| Residuals | Waste | | | | | | | |
| | Air emissions | | | | | | | |
| Total | | | | | | | | |

| Use table (Monetary, Physical and Volume) | | Industries | | | | Final Consumption | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | |
| Products | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| Ecosystem services | Provisioning | | | | | | | | | |
| | Regulating | | | | | | | | | |
| | Cultural | | | | | | | | | |
| Residuals | Waste | | | | | | | | | |
| Primary materials | | | | | | | | | | |
| Total | | | | | | | | | | |

abiotic

biotic

*Figure 3.5 Building block: Biological Dimension*

The issue of substitution between biotic and abiotic materials can be investigated by adding a third dimension to the use table (similar to section 3.3).

### 3.5.2 Potential Indicators

The indicators for ecosystem services can include:

- Value of ecosystem services (euro)
- Percentage of loss during extraction from ecosystem
- Total factor productivity adjusted for ecosystem services (as suggested by the OECD in their green growth indicators).

A useful indicator that concerns the biotic versus abiotic split may be:

- Share of biotic and abiotic inputs per industry

### 3.5.3 Data Availability

*Ecosystem accounts*

Statistics Netherlands is currently working on an ecosystem accounting project that is funded by the Ministry of Economic Affairs. The project uses the information from the DANK database to create ecosystem accounts for the Netherlands. The data should be ready by the end of 2015. One of the ecosystem services is the provision of clean water. Currently CBS is compiling PSUT for ground, surface and tap water. Also the way in which water is used in monitored.

*Biotic/Abiotic*

The product groups of the national accounts could be divided in biotic and abiotic product groups. This could give insight in the cumulative flows of biomass in our economy. The disadvantage of this technique is that certain less interesting bulk flows have a strong impact on the final results, while small, but more relevant flows, such as the use of biotic materials in the chemical industry, cannot be discerned properly.

## 3.6 Building Block: Economic Importance and Control

### 3.6.1 Conceptual Framework

One of the overriding driving forces of the resources literature is to estimate the economic importance of the various concepts. For example, in the Ellen McArthur Foundation studies estimates are made of the savings that might be achieved with respect to the circular economy. Similarly, the McKinsey reports and the reports on the bio based economy try to estimate the economic significance of the transition from a linear to a circular or bio based economy. These studies estimate and highlight the cost savings that might be achieved. It must be realized though that these are estimates based on modelling assumptions.

Nevertheless, it is possible to measure the absolute economic significance of certain environmental phenomena. There are currently two environmental accounts modules available that do just that:

1. *Environmental Goods and Services Sector (EGSS)*. This account quantifies the value added and labour impact of the EGSS. Environmental products are goods and services that are produced for the purpose of preventing, reducing and eliminating pollution and any other degradation of the environment (environmental protection - EP) and p-reserving and maintaining the stock of natural resources and hence safeguarding against depletion (resource management - RM). International definitions exist to define which industries should be included in the EGSS (Eurostat, 2009).
2. *Environmental Protection Expenditure Accounts (EPEA)*. The SEEA central framework defines environmental protection as all actions and activities that are aimed at the prevention, reduction and elimination of pollution as well as any other degradation of the environment. This includes measures taken in order to restore the environment after it has been degraded due to the pressures from human activities (UN et al., 2014a, chapter 4). An account related to the EPEA is the ReMEA (Resource Management Expenditure Accounts) which focusses on the expenditure to manage resources.

Another economic question is who *controls* the companies that are using the resources. Given the number of multinationals, many of the companies that operate in the Netherlands are under foreign control, and many Dutch-owned companies operate

abroad. Recently, van Rossum et al. (2012; 2013; 2014) have calculated the $CO_2$ emission using the control-perspective. Currently a project is being conducted to estimate the percentage of foreign control for each economic activity. The results can hopefully be integrated with the MFM.

### 3.6.2 Potential Indicators

The demarcation of the circular economy does not seem that clear so it seems difficult to calculate the magnitude of the circular economy. For the bio based economy the statistical demarcation seems easier. For example, one could attribute each product group in the MSUT and PSUT the label biotic or abiotic. But then the problem arises how to label the large group of products that have mixed (biotic and abiotic) origins.

The indicators for economic importance would have to quantify the sizes of the various concepts (if possible):

- Value added/employment of EGSS/EPEA/Circular economy/bio based economy (euro / jobs, fte)
- Share of EGSS in technical column/coefficient of sector?

For the economic ownership discussion a number of indicators may be set against the traditional production-based (territorial) and consumption-based (footprint) indicators. Available or shortly from current research at Statistics Netherlands are:

- $CO_2$ emission in the Netherlands by foreign-owned companies
- Share of foreign-owned companies with regards to employment and value added.

### 3.6.3 Data Availability

*Economic significance*

The EGSS and EPEA accounts are already part of the environmental accounts. Some sections might need improvement or extension. (see references in section 4.6.1).

The EGSS is published annually by Statistics Netherlands (van Rossum, 2012) and for the EU by Eurostat.

Recently Statistics Netherlands has invested in the production of the EPEA (Graveland and Schenau, 2012; Schenau and van Velzen, 2013; Schenau, 2014; Graveland et al, 2015). As a basis they use the Environmental Protection Expenditure (EPE) statistics which are the microdata equivalents of the EPEA.

In 2016 Statistics Netherlands will conduct a pilot project to investigate to what extent a ReMEA can be compiled for the Netherlands.

*Economic control*

Van Rossum et al. (2012; 2013; 2014) have estimated $CO_2$ emissions according to the control criterion. They did so by combing the production statistics to the ownership data at the microdata level and by estimating what Dutch companies do abroad.

At the moment Statistics Netherlands is looking to repeat this work but with the focus on employment and value added and for the MFM. The ORBIS database, which achieved

prominence because of a publication on the global control of multinational (financial) corporation (Vitali et al, 2011) may also prove to be useful.

## 3.7 Building Block: Prices, Taxes and Subsidies

### 3.7.1 Conceptual Framework

Prices are an important dimension in the resource debate. Conceptually the prices are part of the MFM framework, because if we divide the monetary supply and tables by the same elements in the physical supply and use tables we obtain the price per kg product.

Prices are influenced by taxes and subsidies. They are one of the ways in which governments can affect resource use as a result of altered producer and/or consumer behaviour. In the Dutch Environmental Accounts there already exist modules on environmental taxes, fees, and subsidies. Figure 3.6 shows how these elements can be added to the MST and MUT –in fact they are already part of the current national accounts.

Figure 3.6 shows that there are two types of taxes and subsidies. Product related taxes and subsidies are proportional to the quantity of the product. These are also shown in the 'third dimension' of the MUT. The product related taxes and subsidies are not dependent on the quantity of product. These are shown in rows of the MUT. Currently, in the Dutch national accounts, they have not been split into the five subtypes of figure 4.6 (eco-taxes, eco-subsidies, harmful subsidies, other taxes and other subsidies) but this could be done rather easily.

The rationale behind eco taxation is to put a 'price' on environmental damages, which are currently not valued in the market.[21] In the Dutch setting an added rationale is that there is a political debate about changing the tax system. There is wide support for lowering taxes on wages and one of the ways to do so would be to increase environmental taxation. The Ex'tax project investigates how 30 billion of tax revenues might be shifted away from labour to environmental issues (Groothuis and Damen, 2014).

Netherlands Environmental Assessment Agency (PBL) has recently published analyses of the situation for the Netherlands (Vollebergh et al, 2014;Vollenbergh, 2014a,b). They also address one of the most discussed problems of eco-taxation: if the eco-taxes that are aimed at reducing environmental damages are successful, this will diminish tax revenues.

[21] Note that the taxes in the MSUT are actual taxes raised. This is different to the theoretical calculations that are done by environmental economist on how high taxes should be (e.g. a Pigouvian tax).

| Monetary Supply Table (MST) | | Industries | | | | | | Product related taxes and subsidies | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Import | **Total** | Eco-taxes | Eco-susidies | Harmful subsidies | Other taxes | Other Subsidies |
| **Products** | Agriculture | | | | | | | | | | | |
| | Mining | | | | | | | | | | | |
| | Industry | | | | | | | | | | | |
| | Services | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | |

| Monetary Use Table (MUT) | | Industries | | | | Final Consumption | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Mining | Industry | Services | Export | Government | Consumers | Investments | **Total** |
| **Products** | Agriculture | | | | | | | | | |
| | Mining | | | | | | | | | |
| | Industry | | | | | | | | | |
| | Services | | | | | | | | | |
| **Value added** | Production related taxes | | | | | | | | | |
| | Production related subsidies | | | | | | | | | |
| | Other Value Added | | | | | | | | | |
| **Total** | | | | | | | | | | |

Eco-taxes
Eco-subsidies
Harmful subsidies
Other taxes and subsidies

*Figure 3.6. Building block: Prices, taxes and subsidies.*

Note that when the eco-taxation is discussed, as the PBL and Ex'Tax reports do, the discussion often focuses on taxes on energy. Taxes on resources are not usually part of the equation. One of the reasons is that resource use is concentrated around a small amount of users, so that the impact would be very concentrated. For example, iron ore is only used by large steel companies operating in a global economy. A unilateral tax on iron ore would affect their competitiveness very directly. A second reason might be that resources are used several times. Iron ore becomes steel, and steel becomes a car. At which stage do you tax the resource? If you do this at each stage, you are taxing the same kg of iron three times. Energy though, is a typical final use product. This means that taxes on energy are imposed just once.

The issue of harmful subsidies is shown in figure 3.6 as well. These are subsidies that have detrimental effects on the environment. The G20 have agreed to phase out these types of subsidies. Recently, Algemene Rekenkamer (2015) published a report with an inventory of (Dutch) subsidies and their impact on the environment. This could be used as a starting point to discern the different types of subsidies in the MFM+. Nevertheless, there is still no clear consensus on which subsidies are harmful and which not.

### 3.7.2 Potential Indicators

There is a number of indicators that may be produced using this building block:

Indicators that can already be derived from the current Environmental Accounts and other ready available statistics are:

- Environmental taxes, fees and subsidies per sector (euro)
- Derived from the International Trade Statistic and the Prodcom: prices for resources and products per kilogram (euro per product, euro per kg).
- Eco-taxes as a share of total tax burden
- Share of taxes in purchasing price of resources and products

Indicators that can be derived if the MFM is extended:

- Harmful subsidies per sector (euro)
- Eco-subsidies and harmful subsidies as a share of total subsidies

### 3.7.3 Data Availability

*Prices*

There is a great deal of information on prices of resources and products available. An example is the website Infomine.com which collects global prices on resources. Statistics Netherlands publishes data on energy prices on StatLine. There are also a few statistics that publish both monetary and physical data from which prices can be derived. This information is already part of the MFM.

*Taxes and subsidies*

In the Netherlands, environmental taxes can be directly obtained from the Environmental Accounts. The information it contains uses the definitions and criteria set by the OECD and Eurostat. The tax revenues are classified by category (energy, transport, pollution and resource taxes) and also by industry/final use and environmental domain.

The total amount of environmental subsidies is part of the environmental accounts. Not yet available is the distribution to the different industries and households. The subsidies can be classified according to the different environmental themes (energy saving, air pollution, water pollution etc.). A preliminary study should be carried out to point out the exact levels of aggregation on which it is possible to construct such subsidy accounts.

Data on harmful subsidies are at least partially available. Drawback is that there is no consensus on what should be considered a harmful subsidy.

## 3.8 Building Block: Quality Labelling

### 3.8.1 Conceptual Framework

One of the ways in which the consumer can be nudged into more environmentally-friendly consumption is by labelling products with a quality label. There is a manifold of sustainability and organic labels around, some of which are given out by the producers of the labelled product themselves. Of course, carrying a quality label is not a guarantee that the products are produced sustainably. Nevertheless, some consumers take these as an important signal and adjust their consumption behaviour. Perhaps if sustainability labels are audited more strictly in the future, they may become even more important.

In order to add this dimension to our accounting system, it would be necessary to split the relevant product or industry groups into a labelled/unlabelled group. For example, milk would be split into an organic labelled and non-labelled in the MSUT and PSUT.

### 3.8.2 Potential Indicators

When the distinction between products with and without a quality label could be introduced to the MSUT and PSUT, some of the indicators might be:

- Share of products that is labelled
- Price differences labelled/unlabelled products
- Share of labelled farms in total agricultural production (value added) (euro)
- Difference in profitability of labelled and unlabelled farms (value added, euro)
- Share of sustainable consumption in total consumption (euro)
- Value added/Employment due to labelled products (euro / jobs / fte)

### 3.8.3 Data Availability

*Labelling*

Statistics Netherlands has recently published the Monitor Duurzame Agro-agro-grondstoffen (CBS, 2013a) in which of the consumption of palm-oil, soya, wood and coffee with an eco-label is presented. The data on the quantity of labelled products are obtained from various sources. In future editions there are plans to add farmed fish, fresh fruit and vegetables (originating from Africa, Asia, South and Central America), Cocoa, cut flowers, potted plants.

In a related project, the Monitor Duurzaam Voedsel is being produced. This projects aims to estimate the share of sustainable food products sold in supermarkets. The data source is ‘scanner-data’. These are obtained by Statistics Netherlands from the supermarkets and contain detailed transaction information which includes the prices and volumes.

For cars, the Statistics Netherlands-database for cars includes information on emission characteristics. This would make it possible to distinguish between cars with high and low emission characteristics.

For electrical products with different energy labels (‘witgoed’) Vlehan (www.vlehan.nl) records sales. ECN uses this data as well as the energy labels for houses (Tigchelaar. and Leidelmeijer, 2013) in their EVA model (Electricteits Verbruik Apparaten). They do

not yet use information from RVO which has information on housing definitive and preliminary labels.

Note that neither of these projects are performed in a national accounts setting. The results would therefore need to be translated to that framework to be consistent to the other accounts of the MFM. This will turn out to be quite a challenge as commodity groups recorded in the MM are not always homogeneous.

## 3.9 Building Block: Eco-Innovation and -Investment

### 3.9.1 Conceptual Framework

If companies want to change their resource profile in the long term they will have to change their technology and/or their business model (see section 4.10 for the latter). Incremental improvements can be achieved but for more fundamental changes, it is necessary to fund innovation and investment. Note that these types of innovation/investment might be done by governments (e.g. university research) or households (e.g solar panels) as well.

Conceptually, innovation (R&D) and investment are already part of the system of national accounts (MSUT) so it would simply be a matter of splitting them into an environmental and non-environmental part. Note that in the PSUT investments are recorded for each commodity but not per industry.

### 3.9.2 Potential Indicators

These indicators that can be derived from distinguishing eco-innovation and eco-investment would be new to the national accounts and would include:

- Share of eco-innovation/R&D in total (euro)
- Share of eco-investment in total (euro)

The indicators might also be split into the environmental themes (for example energy, agriculture, building, recycling) which they address. In order to distinguish between industrial branches or public versus private investments the investments need to be allocated to the economic activity.

### 3.9.3 Data Availability

*Innovation/R&D*

The EPE and EPEA statistics provide information about expenditures on process-innovation.

Note that the Community Innovation Survey (CIS) which is governed by Eurostat includes a module on environmental innovations. However, it is a non-compulsory module which Statistics Netherlands does not include in its CIS-survey for companies.

*Investment*

The EPE and EPEA statistics provide information about expenditures on investments in environmentally friendlier production technologies. Data on the economic activity that makes the investment are available in the national accounts as well.

## 3.10 Building Block: Business Models

### 3.10.1 Conceptual Framework

The publications by the McArthur Foundation provide many examples of companies that adopt so-called 'circular business models'. The business models of this kind all show increased interaction between manufacturer, retailer and consumer. They allow for high levels of reuse, remanufacture, repair and recycling. In cases where scarce materials are involved, the producers retain increased control over these scarce resources. One of the ways of changing the business model is that companies 'lease' their products rather than sell them. The advantage is that the products will return to company and that this will improve the ability to remanufacture and recycle goods.

Part of this model is also to 'design out waste' from the products.
Other forms of innovative business models mentioned by the McArthur Foundation are performance-for-pay models, rent schemes and return and reuse.[22]

The corresponding building block would distinguish between these circular types of business models and other types of business models. Next to that, it should be able to show the flows of reused product in its production process.

### 3.10.2 Potential Indicators

Examples of indicators that may be derived from this building block, relevant for the policy discussions on resources use:

Indicators that can already be derived from the current MSUT are:

- Total value of leasing / renting per year (euro).

Indicators that can be derived if the MFM is extended with data on leasing / renting (as an industry):

- Total amount of material used for leasing / renting, by companies specialized in leasing / renting (kg).

In addition it would be very interesting to have an indicator that measures the intermediate use of reused material within the leasing/renting industry:

- Change in amount of material (re)used for leasing / renting purposes (kg)
- Amount of products taken back by manufacturers (volume in numbers and in kg)

### 3.10.3 Data Availability

*Business model (leasing)*
Leasing is part of the national accounts but this includes all forms of leasing. Cars and airplanes are frequently leased and well registered in the national accounts. Other data on leasing or other business models are available.

[22] Some examples of circular business models can be found at: http://reports.weforum.org/toward-the-circular-economy-accelerating-the-scale-up-across-global-supply-chains/how-it-works-up-close-case-examples-of-circular-products/

We know of no database in which there are data on the changes in environmentally friendly business models (including leasing).

*Product design*

We have found no potential data sources.

## 3.11 Building Block: Spatial Scales (International, National, Regional and Local)

### 3.11.1 Conceptual Framework

The problems and solutions related to resource use may exist at different levels. Some problems may have a global dimension (scarcity of critical materials) or a local dimension (wastes in cities). On the other hand solutions may also present themselves at national level (energy tax) or regional level (collection of electronic waste). Currently, the MFM is a national accounting structure but conceptually it can easily be expanded to cater to several spatial scales.

*International dimension*

The MFM currently available at Statistics Netherlands already contains an international dimension. Import and export of materials can be differentiated to country of origin or destination. The PSUT can be expanded even further to create an international PST and PUT as shown in Figure 3.7. The table shows the transboundary flows, in physical units, between the Netherlands and the Rest of the World (ROW).

The monetary equivalent of Figure 3.7 is used by just about all the major multi-regional input-output (MRIO) databases that are around (WIOD, Eora, EXIOBASE, OECD). From the MST and MUT, input-output tables are produced. These are needed to calculate carbon, water and material use. The global MRIO allows us to calculate for example the ‘footprints’ of Dutch consumption. Such ‘consumption-based’ indicators are important in debates on environmentally sustainable consumption.

It is not necessary though to have an MRIO-database in order to determine the embodied materials in consumption. Schoer et al. (2012) developed a database to calculate an indicator called Raw Material Equivalents (RME). In the MFM the RME of import is already incorporated. Currently research is being conducted by Statistics Netherlands to improve their methodology to convert export flows in products to their raw material equivalents.[23]

*Regional and local dimension*

Recently, circular economy initiatives have also become popular at the city or regional level (e.g. the “Vang Lokaal” initiative of the ministry of infrastructure and the environment). Also, Horizon2020 calls are dealing specifically with local resource use. Figure 3.7 could quite easily be expanded to show the regional and city dimensions.

[23] Note also that it would be useful to link the monetary and physical accounts to the global asset accounts. By doing so the global production of resources and their consumption in individual countries could be identified (Wiedmann et al., 2013).

| Physical Supply Table (PST) | | | Industries | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Netherlands | | | | ROW | | | | |
| | | | Agriculture | Mining | Industry | Services | Agriculture | Mining | Industry | Services | **Total** |
| **Products** | Netherlands | Agriculture | | | | | | | | | |
| | | Mining | | | | | | | | | |
| | | Industry | | | | | | | | | |
| | | Services | | | | | | | | | |
| | ROW | Agriculture | | | | | | | | | |
| | | Mining | | | | | | | | | |
| | | Industry | | | | | | | | | |
| | | Services | | | | | | | | | |
| **Residuals** | Waste | | | | | | | | | | |
| | Air emissions | | | | | | | | | | |
| **Total** | | | | | | | | | | | |

| Physical Use Table (PUT) | | | Industries | | | | | | | | Final Consumption | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Netherlands | | | | ROW | | | | Netherlands | | | ROW | | | |
| | | | Agriculture | Mining | Industry | Services | Agriculture | Mining | Industry | Services | Government | Consumers | Investments | Government | Consumers | Investments | **Total** |
| **Products** | Netherlands | Agriculture | | | | | | | | | | | | | | | |
| | | Mining | | | | | | | | | | | | | | | |
| | | Industry | | | | | | | | | | | | | | | |
| | | Services | | | | | | | | | | | | | | | |
| | ROW | Agriculture | | | | | | | | | | | | | | | |
| | | Mining | | | | | | | | | | | | | | | |
| | | Industry | | | | | | | | | | | | | | | |
| | | Services | | | | | | | | | | | | | | | |
| **Residuals** | Netherlands | Waste | | | | | | | | | | | | | | | |
| | ROW | Waste | | | | | | | | | | | | | | | |
| **Primary materials** | | | | | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | | | | |

*Figure 3.7. Building block: Spatial scales (International dimension)*

## 3.11.2 Potential Indicators

Indicators that can already be derived from the current MFM are:

- Material (Resource) footprint of imported products (Raw Materials Equivalents)
- Energy dependency
- Self-sufficiency-share of domestic versus imported resources
- Trade of resources per country (including war-torn or developing countries) (euro and kg)

Indicators that can be derived when the MFM is embedded in a MRIO:

- Carbon, Water, Land, Biodiversity and Material (Resource) footprints
- Place of the Netherlands in the global value chain for resources

When combined with asset accounts other indicators are possible:

- Dutch natural resources as a share of global resources
- Share of Dutch consumption in global reductions in resources

Indicators at the regional level could be:

- Carbon, Water, Land, Biodiversity and Material (Resource) footprints at the regional, municipal or city level

### 3.11.3 Data Availability

*International dimension*

All major MRIO database are creating global MST and MUT accounts but only EXIOBASE is currently trying to create a physical version of these tables. This will prove to be a valuable addition for studies on the international dimension of resource use.

One of the drawbacks of MRIO databases is that they are not consistent to the data from statistical offices. This is because, in the process of consolidating the database, the original data need to be altered in order to provide a consistent set of data. This is why at Statistics Netherlands a method has been developed to adjust MRIO database to conform to the national accounts data as well making use of the most detailed trade data (Edens et al., 2015). This new method can only be tested when the MRIO of EXIOBASE becomes available.

Further note that data on import and export per industry are available, but that a lot of the import and export is being carried out by trading companies. This makes it difficult to couple the product flows to the actual producers.

Data on import and export can easily be discerned to country of origin / destination. The data is already available in the current MFM.

At Statistics Netherlands a project was conducted to connect RME to the MFM. It turned out to be possible to convert the import of the MFM to RME after some assumptions were made. One issue we ran into was that the import of services should also be included. However, services are not part of the MFM. The export in the MFM could not be converted to RME. In order to do this, Dutch domestic extraction needs to be allocated to exports by using input-output analyses.

*Regional and local dimension*

In terms of regional data, the national accounts department publishes the 'regional accounts' which provide data for each COROP area. However, these data are very aggregated, and only in monetary terms. The micro-data would need to be revisited to work at a level of aggregation that would be of use to resource issues.

# 4. Data Availibility and the MFM+

Chapter 3 discussed the conceptual details of the ten potential ways to expand the MFM. Each building block will need a certain investment of resources. There are two criteria that are crucial in this investment decision:

- The feasibility (in terms of data availability) of the building block. This will be covered in the remainder of this chapter.
- The policy questions that may be answered. This will be covered in the next chapter.

Based on the analysis of the data availability in Chapter 3, we have categorized the building blocks into three types: Good, Fair and Poor data availability.

*Good: Building blocks that are already available or under development*

- *Assets*. A variety of natural resource accounts are already available and ecosystem accounts are being developed. Urban assets in physical terms are only available to a limited extent.
- *Economic importance and control*. Accounts for EPEA and EGSS are already available and accounts for ReMEA are being developed. Calculations for a bio based protocol have been developed by researchers from RVO/Wageningen University. Estimations of ownership of Dutch industrial branches are being further developed
- *Prices, taxes and subsidies*. Many of the relevant taxes and subsidies are already included in the current environmental accounts. Prices could be calculated simply by division of the monetary and physical accounts.
- *Spatial Scales*. Currently, the DESIRE project (led by TNO/CML) is being finalized. It is expected that there will be a time-series of global PSUTs and MSUTs. These could be connected to the Dutch MFM by applying the SNAC-methodology (Edens et al, 2015). In a SNAC the MRIO is adjusted in a way that it is consistent with national data of a country. This is necessary because country specific data in a MRIO does not always match national data. Merciai et al., (2013) look specifically at the relationship between the Dutch MFM and the EXIOBASE.
- *Eco-Innovation and -Investment*. The data underlying the environmental expenditure accounts provide a good basis for a special module on eco-innovation and expenditures. Essentially it would be making use of the data from the current EPEA.

*Fair: Building blocks that are partially feasible*

- *Technology*. Although there is no centralized database on technology and product composition there is quite a bit of literature with partial information on product composition. For the WEEA sector this is already quite advanced. Also TNO compiled a table with the 'critical' material content per commodity. This table was linked with the MFM in order to estimate the use of 'critical' materials by industrial branch (Bastein, 2014). This study is currently being broadened to include more critical materials (TNO et al, 2015). Also Eurostat developed coefficients that can be used to convert data in the MFM to their raw material equivalents (RME) (IFEA, 2012).

- *Labeling*. There are data for a couple of relevant products. The challenge is to match these products with products in the MFM.
- *Biological Dimension.* Identifying the biotic and abiotic dimension of the economy seems difficult, given the data that is being developed under the bio based protocol. The level of detail in the current MFM is not always sufficient. However a coarse indication of biomass flows can be provided in the current MFM (Delahaye and Zult, 2013) by allocating products to their composition.

*Poor: Building blocks that would need extra data sources*

- *Residuals*. Only wastes and recycling are covered adequately in the data sources but reuse, repair and remanufacturing are not covered sufficiently.
- *Business model*. We found no information on the various business models that might contribute to a more efficient use of resources by firms.

# 5. Policy Questions and the MFM+

Of course, the most important reason to expand the MFM is because it can be used to answer policy questions that cannot be tackled at the moment. The choice of policy questions (and the necessary building blocks) is decided in political processes. It seems useful to explore a number of policy questions because this enables us to see which building blocks are important.

Below you will find a list of twelve policy questions. We have derived these from the literature that we covered in chapter 2, 'Tussenbalans groene groei' and conversations with resource experts and policy makers. These policy questions were also discussed during a workshop with resource experts and policy makers at the ministry of economic affairs on July 10th 2015.

For each question we will discuss:

- Which building blocks are necessary to answer the policy question.
- Which methods could be used to analyse the research question. The technical details of these methods are described further in annex 4.

The first three policy questions are very much related to the physical dimension of the economy.

*1. How close is the economy to circularity?*

One of the most fundamental long-term goals of the circular economy is to reduce the use of non-renewable virgin material to zero while using biological sources in a sustainable way. It would be best if there were indicators to measure to what extent an economy is circular. The reports by the Ellen McArthur Foundation (2015b,c) are interesting because they provide a tool for companies to assess their circularity compared to other companies on a continuous scale.

Building blocks and models: This question could be answered with data from the current MFM on extraction of virgin materials and biomass but also from the data from the circularity of residuals building block with regards to recycling, reuse and repair. These building blocks could provide the basis for a circularity index. Note however that we assessed the data availability on reuse and repair of the residuals building block to be poor.

*2. What drives current and future changes in material use?*

To understand change in resource use, or to project materials use into the future, it is important to analyse which are most important driving forces. For example, economic growth, increase in exports or consumption will lead to increases in resource use. On the other hand, technological advances, longer product lifetimes or increase in recycling, reuse and remanufacturing lead to reductions in material use. Technological changes or changes in product composition could lead to shifts in the materials being used.

Building blocks and models: To analyse historical developments it is possible to use (structural) decomposition analysis which calculated the contribution of a variety of different driving forces. The current MFM combined with the current input-output tables (in current and prices of previous year) would already provide a good basis for most of the effects (consumption, exports, technology, intensities). In addition it would be useful

to include the building block on residuals and the international dimensions. If the building blocks on technology and biological dimension were available the analyses could be expanded to include the impact of product composition and the shift from abiotic to biotic.

Various models, based on the MFM+, might also be used to project material use. These could take various forms (scenario analyses, static or dynamic CGE models).

*3. In what way can the economy shift from the use of abiotic to biotic sources?*

One of the fundamental shifts which are advocated in the literature is to go from non-renewable resources to biological sources. The MFM+ can help to account for this change and help model it.

Building blocks and models: Obviously the building blocks *biological dimension* and *assets* (ecosystems) would be used to answer this question. The split between biotic and abiotic materials (similar to the third dimension of the building block *technology* would be very useful, but to fully model this aspect it is also important to know, in detail about various technological developments in which biological resources may play a role.

The next three policy questions are mostly do with economic potential of some resource concepts.

*4. What is the economic potential of the Circular Economy/Bio Based Economy?*

The literature on circular economy and bio based economy focus very much on the economic opportunities that they may provide. In the case of the bio based economy it can be expressed as a percentage for a relevant industrial sector like the chemical industry. In the case of the calculations for the circular economy it is more a question of calculating the savings that could be made by reducing resource use.

Building blocks and models: Obviously the building blocks on *circularity of residuals* and *economic importance and control* are vital to understand these questions. In the case of the circular economy a 'what-if' model has to be built which calculates what would happen if the economy became more circular.

*5. What is the value of the services provided by nature?*

Nature, through its ecosystems, plays a vital role in providing services to society. These services are not always assigned a price which is why it is of interest to estimate what the value is of the ecosystems services provided.

Building blocks and models: The building blocks *biological dimension* and *assets* (ecosystems) would be used to answer this question. There is already a study underway at Statistics Netherlands.

*6. Which resources can be exploited in a commercially viable way from urban mining?*

The materials embodied in the various urban mines that exist (landfills, products and buildings) could at some stage become a viable source of resources. An assessment of the economic availability to mine these sources for materials would be very useful for policy makers.

Building blocks and models: The building blocks on *assets* (urban mining) would be used to answer this question. It would have to be combined with information about the lifespan of assets, the costs of collecting and processing in order to assess the viability.

The next two policy questions have to do with the consequences that changes in resource use might have on other (environmental, economic or social) aspects.

7. *Does resource efficiency lead to improvements in other environmental pressures and/or does it has social repercussions?*

Changes in resource efficiency may have beneficial or detrimental effects on other environmental and social aspects (e.g. the use of high-skilled or low-skilled labour).

Building blocks and models: The current MFM and the building blocks on *residuals* could be combined with other SEEA accounts (such as on water pollution) or socio-economic satellite accounts (such as labour accounts). They may be analysed in decomposition analysis or in CGE models.

8. *What are the environmental, economic and fiscal implications of a shift from labour to green taxes?*

This is similar to the question above but specifically looks at the implications of changing the tax system. Again this might have varying impacts on the environment and society.

Building blocks and models: The building blocks on *prices, taxes and subsidies* would be used to answer this question. Other accounts about government revenue, other SEEA accounts (such as on water pollution) or socio-economic satellite accounts (such as labour accounts) would be included as well. These could be combined in a CGE model.

The next policy question is related to consumer behaviour.

9. *In what way can consumers be nudged towards a more resource efficient society (prices, labelling, sharing society) and what role do concepts such as the rebound effect play?*

Changing consumer behaviour is of interest to policy because this may help transition to a circular economy and may also influence producers as well.

Building blocks and models: The building blocks on *prices, taxes and subsidies, labelling, business model* and the current MFM data could be combined to analyse this type of question.

The next three questions have to do with the regional and international aspects of resource flows.

10. *What is the potential for regional or city level circular economy initiatives?*

There is increasing demand for analysis for regions or cities rather than at the national level.

Building blocks and models: The building blocks on *spatial scales* could be used to analyse this type of question.

11. *What is the impact on natural capital in other countries as a result of demand and sourcing behaviour in the Netherlands?*

One of the dimensions of sustainable development is to analyse the impact of our behaviour on other countries (“elsewhere”).

Building blocks and models: The building blocks on *spatial scales* could be used. Not only could it be used create footprint measures, but it may also be used for decomposition analysis to understand the impact of sourcing of intermediate good and final goods from other countries.

*12. Which industries are most dependent on resources from abroad, in particular critical materials?*

The measure of dependence of industries on foreign (critical) materials varies. With dependence comes economic risk which it why it is a relevant policy issues. TNO is currently developing a toolset for companies to assess their dependence/risk.

Building blocks and models: The building blocks on *spatial scales* should be used and combined the building block on *technology*. It can then be combined with the regular monetary SUT to assess dependency per sector.

*Conclusions of workshop*

On July 10th 2015 a workshop was held about a previous version of this report. The above twelve policy issues were discussed at length. Below we have summarized some of the discussion that took place on that day:

- The importance of the spatial scales in resources research was stressed. Some argues that the city level was the most important dimension for resources. On the other hand, other participants argued that resources need to be analysed using a global perspective.
- It was stressed that it was important to look at all the effects (environmental, social and economic) of shifts to a circular economy, because there are both positive and negative aspects of reductions in material use. The impacts on biodiversity were highlighted.
- Similarly a shift to a bio based economy will have several positive and negative impacts.
- It was noted that macro-economic data is useful for monitoring purposes but that sometimes micro data or regional data is necessary to provide actionable information.
- The importance of closing production chains ("sluiten van ketens") in resource management was highlighted.
- There was scepticism of the way in which the circular economy has been quantified to date, but at the same time the importance of these estimates was stressed.
- Some argued that shifting towards the circular economy is too often rationalized out of economic gain.
- The idea was raised to create a database of products characteristics which could be put to use in global research on resources.
- The emergence of new business models was seen as in important area of statistical work (although it was understood that it was difficult to collect data).

These and the other comments by the workshop participants have helped to improve this report and to shape the conclusions in the next chapter.

# 6. Conclusions and Moving Forward

## 6.1 Conclusions

This report provides a broad assessment of the feasibility of an expanded material flow monitor (MFM+). The current MFM is an account that is part of the System of Environmental and Economic Accounts (SEEA). The MFM+ addresses new policy questions that the current MFM is unable to answer. To do so we have defined ten building blocks that may be used to expand the MFM. They are described conceptually and potential indicators are discussed. The feasibility (in terms of data availability) are assessed and their potential to assess policy questions. We conclude that:

- MFM is a flexible, standardized accounting system that can be adapted to address new policy questions on resources
- The ten building blocks of the MFM+ provide a framework for connecting the various research question in coherent measurement systems
- MFM+ yields many useful indicators to monitor resource policies
- Various policy questions can be addressed by the various building blocks
- Only two of the ten building blocks seem to lack appropriate information (business models and circularity of residuals).

## 6.2 Moving forward

How to move forward after this report? There are number of options that seem worthwhile.

*Select the most important policy questions*

Policy makers will have to assess which of the policy questions discussed in chapter 5 are the most important. This may also lead to other policy questions being defined. Based on this prioritisation, the building blocks that need to be built may be chosen.

*Consider new ways to observe the building block 'circularity of residuals' and 'business models'.*

The largest data gap that was found is related to information on reuse, repair and remanufacturing as well as the data on business models.

*Create links between the state-of-the-art research centres*

The Netherlands is host to many groups and research units which can be considered state of the art in the Europe and beyond (CBS (SEEA. MFM, Sustainable Development), CML (international dimension), CE-Delft (policy analysis), Ex-tax (eco-taxation), PBL (policy analysis and eco-taxation), TNO (technology, circular economy and critical materials),The Sustainability Consortium (product impacts), Utrecht University (circular economy), UN University (WEEE), Wageningen University (ecosystem services and bio based economy)).
Nevertheless, these work on very different fields within the realm of resource issues. By looking at these projects through the lenses of a coherent, standardized accounting

system such as the MFM+, the linkages are stressed. This may lead to new ideas on how these projects may collaborate in terms of data and analysis.
These Dutch institute will also be in contact with other state of the art research centres in Europe, Japan or elsewhere. It is very important to work together and expand cooperation with these organisations.

### *Promote the use of MFM/MFM+ in policy analysis*

The current MFM and its potential expansions (MFM+) are not just aimed at creating data and indicators: they should also be used in policy models. Some of these analyses may be done by Statistics Netherlands but the most advanced models (such as CGE) are beyond the mandate of our institute. It is important to actively promote the use of the MFM by other institutes in order to increase its usefulness to society and policy making in particular.

### *Further explorations in statistical work*

Statistically speaking we have found areas in which data is of great quality but also areas where it is poor/non-existent. There are three aspects of the statistics which we would feel are useful for further exploration:

1. *Modelling*. As the 'critical' material, RME conversion tables and WEEE projects have shown, data are partially being produced by modelling. Note that these are models such as the perpetual inventory model where data on some variable (investments, life time of the a electronic machines) are used to create an estimate of an unobserved quantity (stocks of electronic machines). In these cases only directly related variable are used in the model. This might also be a worthwhile strategy to explore in the creation of the MFM+.
2. *Micro-macro links/aggregation*. In essence many resource issues have a micro and macro dimension. In some cases, like EGSS, micro data can be used in this macro-oriented MFM. However, in the MFM+ the link between micro and macro level data needs to be further explored in order to be suitable for research questions on, for example, the bio based economy and labelling.
3. *Technological information*. The MFM will benefit greatly from greater use of technological information in the production of the accounts. If more technological data could implemented this could lead a MFM+ with an adjusted compilation method.

### *Spatial scales*

One of the dominant lines of research seems to be to connect the various spatial scales that exist for resource policy. Problems and solutions may occur at the global, national, regional and local level. It is very valuable to analyse these in a coherent integrated measurement system. These scales are increasingly becoming available in various database such as Eora and EXIOBASE.

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# Annex 1. Consultations

Various versions of the report have been submitted for feedback. The report was sent round for comments in the month of May.

At three moments the report was presented:

| Location | Type of meeting | Date |
|---|---|---|
| CML (Leiden, The Netherlands) | Presentation | March 24th 2015 |
| Input-output conference (Mexico City, Mexico). Special session on circular economy. | Conference | June 23-26th 2015 |
| Presentation of final report (Ministry of Economic Affairs, The Netherlands) | Discussion of the report | July 10th 2015 |

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2. Geert Warringa, CE Delft
3. Ton Bastein, TNO
4. Elmer Rietveld, TNO
5. Gert-Jan Sikking, PGGM
6. Mattheus van de Pol, directie Groene Groei en Biobased Economy, ministerie van Economische Zaken
7. Evert Visser, directie Algemene Economische Politiek, ministerie van Economische Zaken
8. Tjeerd Meester, directie Duurzaamheid, ministerie van Infrastructuur en Milieu
9. Koert Ruiken, directie Duurzaamheid, ministerie van Infrastructuur en Milieu
10. Jan Pieter Barendse, directie Inclusieve Groene Groei, ministerie van Buitenlandse Zaken
11. Kees Kwant, programma Concurrerende en duurzame energiesectoren, Rijksdienst voor Ondernemend Nederland

# Annex 2. Material Flow Monitor 2010

| | Agriculture, forestry and fishing | Mining industry | Manufacture of food products, beverages and tobacco products | Manufacture of textiles, wearing apparel and leather products | Manufacture of wood and paper products | Manufacture of coke and refined petroleum products | Manufacture of chemicals and pharmaceutical products | Manufacture of rubber and plastics products | Manufacture of other non-metallic mineral products | Manufacture of basic metals | Manufacture of metal products, except machinery and equipment | Manufacture of computer, electronic and optical products | Manufacture of electrical equipment | Manufacture of machinery and equipment n.e.c. | Manufacture of transport equipment | Manufacture of furniture and other manufacturing a | Electricity, gas and steam supply | Water treatment and supply; sewerage; waste treatment | Construction | Services | Total collum 1–20 | Consumption households | Accumulation | Import | Flows from the environment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 1 Products of agriculture, forestry and fishing | 26 917 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 26 948 | | | 25 609 | | 52 557 |
| 2 Products of cattle breeding | 16 675 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 675 | | | 1 170 | | 17 845 |
| 3 Fossil energy carriers | 0 | 70 183 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 928 | 0 | 0 | 0 | 0 | 0 | 0 | 98 | 0 | 0 | 0 | 71 234 | | | 98 283 | | 169 517 |
| 4 Other mining products | 0 | 23 430 | 914 | 0 | 0 | 0 | 4 328 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 367 | 3 866 | 45 000 | | | 52 137 | | 97 137 |
| 5 Fish and meat products | 129 | 0 | 3 907 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 4 056 | | | 2 948 | | 7 004 |
| 6 Potato, vegetable and fruit products | 0 | 0 | 4 266 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 766 | 5 032 | | | 3 998 | | 9 030 |
| 7 Diary products | 48 | 0 | 4 904 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 107 | 5 059 | | | 2 289 | | 7 348 |
| 8 Grain mill and starch products | 0 | 0 | 4 478 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 104 | 4 582 | | | 3 422 | | 8 004 |
| 9 Other food products | 0 | 271 | 26 630 | 0 | 1 | 0 | 610 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 226 | 27 738 | | | 7 426 | | 35 164 |
| 10 Beverages and tobacco products | 0 | 0 | 6 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 6 276 | | | 3 237 | | 9 513 |
| 11 Textiles, w earing apparel and leather products | 0 | 0 | 0 | 583 | 9 | 0 | 39 | 1 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 36 | 675 | | | 1 617 | | 2 292 |
| 12 Wood products, except furniture | 0 | 0 | 0 | 0 | 2 320 | 0 | 0 | 150 | 1 | 0 | 11 | 0 | 0 | 0 | 0 | 128 | 0 | 0 | 1 | 71 | 2 682 | | | 3 786 | | 6 468 |
| 13 Printing and paper products | 0 | 0 | 0 | 1 | 5 450 | 0 | 0 | 18 | 0 | 6 | 5 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 47 | 5 536 | | | 6 525 | | 12 061 |
| 14 Coke and refined petroleum products | 0 | 0 | 0 | 0 | 0 | 58 357 | 2 530 | 0 | 0 | 2 547 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 938 | 72 372 | | | 68 426 | | 140 798 |
| 15 Chemical and pharmaceutical products | 5 | 255 | 330 | 1 | 6 | 344 | 44 132 | 40 | 3 | 37 | 3 | 8 | 60 | 6 | 0 | 28 | 0 | 548 | 0 | 510 | 46 316 | | | 35 740 | | 82 056 |
| 16 Rubber and plastic products | 0 | 0 | 0 | 2 | 24 | 0 | 41 | 2 465 | 6 | 6 | 15 | 3 | 14 | 8 | 0 | 26 | 0 | 0 | 0 | 39 | 2 649 | | | 3 483 | | 6 132 |
| 17 Other non-metallic mineral products | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 31 | 24 887 | 37 | 18 | 27 | 40 | 0 | 0 | 1 | 0 | 0 | 181 | 410 | 25 634 | | | 9 008 | | 34 642 |
| 18 Basic metals | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 0 | 0 | 9 986 | 400 | 0 | 9 | 9 | 2 | 0 | 0 | 0 | 0 | 21 | 10 434 | | | 11 548 | | 21 982 |
| 19 Metal products, except machinery | 0 | 0 | 11 | 3 | 41 | 0 | 0 | 20 | 12 | 63 | 3 737 | 6 | 18 | 90 | 20 | 37 | 0 | 0 | 245 | 33 | 4 336 | | | 2 512 | | 6 848 |
| 20 Machinery and equipment | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 10 | 5 | 65 | 158 | 414 | 1 037 | 3 506 | 52 | 40 | 0 | 0 | 0 | 314 | 5 606 | | | 7 348 | | 12 954 |
| 21 Transport equipment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 51 | 18 | 0 | 0 | 11 | 2 684 | 17 | 0 | 0 | 4 | 9 | 2 806 | | | 2 688 | | 5 494 |
| 22 Furniture and other manufactured goods | 0 | 0 | 0 | 5 | 1 143 | 0 | 1 | 0 | 0 | 0 | 8 | 1 | 0 | 1 | 0 | 768 | 0 | 0 | 0 | 793 | 2 720 | | | 1 606 | | 4 326 |
| 23 Total row 1–22 | 43 774 | 94 139 | 51 682 | 599 | 8 998 | 58 726 | 51 688 | 2 842 | 24 914 | 13 726 | 4 376 | 459 | 1 178 | 3 632 | 2 758 | 1 086 | 98 | 548 | 12 798 | 16 345 | 394 366 | | | 354 806 | | 749 172 |
| 24 Waste and recycled products | 74 596 | 66 | 7 510 | 71 | 1 081 | 594 | 1 217 | 161 | 739 | 1 856 | 401 | 20 | 54 | 168 | 117 | 263 | 1 140 | 16 887 | 18 599 | 5 136 | 130 676 | 9 297 | 6 059 | 15 350 | 0 | 161 382 |
| 25 Extraction | | | | | | | | | | | | | | | | | | | | | | | | | 143 679 | 143 679 |
| 26 Balancing item | 75 143 | 3 942 | 22 749 | 398 | 2 567 | 15 894 | 27 015 | 382 | 5 706 | 9 205 | 771 | 438 | 287 | 584 | 347 | 1 019 | 86 997 | 16 048 | 64 542 | 88 265 | 422 299 | 85 219 | 0 | | 282 455 | 789 973 |
| 27 Total | 193 513 | 98 147 | 81 941 | 1 068 | 12 646 | 75 214 | 79 920 | 3 385 | 31 359 | 24 787 | 5 548 | 917 | 1 519 | 4 384 | 3 222 | 2 368 | 88 235 | 33 483 | 95 939 | 109 746 | 947 341 | 94 516 | 6 059 | 370 156 | 426 134 | 1844 206 |

| | Agriculture, forestry and fishing | Mining industry | Manufacture of food products, beverages and tobacco products | Manufacture of textiles, wearing apparel and leather products | Manufacture of wood and paper products | Manufacture of coke and refined petroleum products | Manufacture of chemicals and pharmaceutical products | Manufacture of rubber and plastics products | Manufacture of other non-metallic mineral products | Manufacture of basic metals | Manufacture of metal products, except machinery and equipment | Manufacture of computer, electronic and optical products | Manufacture of electrical equipment | Manufacture of machinery and equipment n.e.c. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 Products of agriculture, forestry and fishing | 5 456 | 0 | 26 373 | 10 | 331 | 0 | 35 | 53 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2 Products of cattle breeding | 501 | 0 | 15 061 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Fossil energy carriers | 3 928 | 905 | 1 560 | 87 | 566 | 57 633 | 9 396 | 69 | 597 | 4 664 | 129 | 56 | 57 | 131 |
| 4 Other mining products | 1 076 | 2 928 | 35 | 14 | 29 | 0 | 1 645 | 5 | 17 209 | 7 975 | 10 | 0 | 0 | 11 |
| 5 Fish and meat products | 0 | 0 | 1 154 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 Potato, vegetable and fruit products | 5 | 0 | 1 214 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 Diary products | 4 | 0 | 2 139 | 0 | 0 | 0 | 145 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 Grain mill and starch products | 99 | 0 | 4 126 | 0 | 129 | 0 | 30 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 Other food products | 10 244 | 0 | 7 227 | 0 | 11 | 0 | 182 | 19 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 Beverages and tobacco products | 5 | 0 | 403 | 0 | 3 | 0 | 9 | 5 | 0 | 0 | 13 | 5 | 5 | 7 |
| 11 Textiles, w earing apparel and leather products | 6 | 0 | 4 | 210 | 44 | 0 | 6 | 18 | 6 | 0 | 5 | 1 | 2 | 2 |
| 12 Wood products, except furniture | 85 | 2 | 208 | 4 | 988 | 3 | 119 | 62 | 61 | 17 | 156 | 9 | 18 | 91 |
| 13 Printing and paper products | 21 | 1 | 818 | 17 | 4 134 | 2 | 78 | 67 | 24 | 19 | 54 | 40 | 5 | 71 |
| 14 Coke and refined petroleum products | 630 | 40 | 54 | 6 | 16 | 4 458 | 11 783 | 6 | 75 | 2 482 | 49 | 7 | 455 | 20 |
| 15 Chemical and pharmaceutical products | 1 677 | 54 | 504 | 267 | 394 | 721 | 27 881 | 1 799 | 178 | 92 | 156 | 138 | 96 | 134 |
| 16 Rubber and plastic products | 102 | 1 | 472 | 19 | 231 | 3 | 163 | 270 | 130 | 6 | 86 | 17 | 50 | 125 |
| 17 Other non-metallic mineral products | 60 | 0 | 357 | 0 | 53 | 0 | 170 | 9 | 4 387 | 70 | 81 | 18 | 51 | 14 |
| 18 Basic metals | 0 | 0 | 0 | 1 | 32 | 0 | 109 | 93 | 169 | 1 439 | 3 487 | 101 | 184 | 1 485 |
| 19 Metal products, except machinery | 5 | 0 | 206 | 0 | 36 | 2 | 46 | 3 | 12 | 2 | 596 | 37 | 5 | 702 |
| 20 Machinery and equipment | 6 | 3 | 13 | 0 | 1 | 1 | 4 | 1 | 1 | 2 | 73 | 228 | 149 | 641 |
| 21 Transport equipment | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| 22 Furniture and other manufactured goods | 1 | 3 | 70 | 6 | 12 | 2 | 16 | 3 | 4 | 2 | 10 | 34 | 5 | 16 |
| 23 Total row 1–22 | 23 912 | 3 937 | 61 998 | 695 | 7 010 | 62 825 | 51 817 | 2 484 | 22 853 | 16 770 | 4 907 | 691 | 1 084 | 3 450 |
| 24 Waste and recycled products | 76 602 | 11 | 6 719 | 53 | 3 576 | 0 | 1 059 | 598 | 1 731 | 1 905 | 28 | 0 | 206 | 462 |
| 25 Extraction | 38 778 | 91 055 | 923 | 0 | 0 | 0 | 5 000 | 0 | 4 117 | 0 | 0 | 0 | 0 | 0 |
| 26 Balancing item | 54 221 | 3 144 | 12 301 | 320 | 2 060 | 12 389 | 22 044 | 303 | 2 658 | 6 112 | 613 | 226 | 229 | 472 |
| 27 Total | ##### | 98 147 | 81 941 | 1 068 | 12 646 | 75 214 | 79 920 | 3 385 | 31 359 | 24 787 | 5 548 | 917 | 1 519 | 4 384 |

| | Manufacture of transport equipment | Manufacture of furniture and other manufacturing a | Electricity, gas and steam supply | Water treatment and supply; sewerage; waste treatment | Construction | Services | Total collum 1–20 | Consumption households | Accumulation & other final demand | Export domestic | Re-export | Flows to the environment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 1 Products of agriculture, forestry and fishing | 0 | 1 | 0 | 0 | 12 | 1 570 | 33 842 | 2 344 | 133 | 8 682 | 7 556 | | 45 001 |
| 2 Products of cattle breeding | 0 | 0 | 0 | 0 | 0 | 305 | 15 869 | 93 | 83 | 1 515 | 285 | | 17 560 |
| 3 Fossil energy carriers | 72 | 29 | 19 808 | 105 | 209 | 5 958 | 105 959 | 9 370 | 2 206 | 39 200 | 12 782 | | 156 735 |
| 4 Other mining products | 0 | 106 | 0 | 15 | 38 807 | 5 125 | 74 990 | 170 | - 199 | 14 265 | 7 911 | | 89 226 |
| 5 Fish and meat products | 0 | 0 | 0 | 0 | 0 | 557 | 1 763 | 977 | 10 | 3 166 | 1 088 | | 5 916 |
| 6 Potato, vegetable and fruit products | 0 | 0 | 0 | 0 | 0 | 962 | 2 181 | 1 783 | 100 | 3 426 | 1 540 | | 7 490 |
| 7 Diary products | 0 | 0 | 0 | 0 | 0 | 694 | 2 982 | 1 794 | - 30 | 2 197 | 405 | | 6 943 |
| 8 Grain mill and starch products | 0 | 0 | 0 | 2 | 38 | 247 | 4 673 | 196 | 116 | 2 214 | 805 | | 7 199 |
| 9 Other food products | 0 | 0 | 64 | 0 | 0 | 1 351 | 19 098 | 3 734 | 104 | 10 460 | 1 768 | | 33 396 |
| 10 Beverages and tobacco products | 4 | 5 | 0 | 0 | 28 | 3 062 | 3 554 | 2 281 | 102 | 3 049 | 527 | | 8 986 |
| 11 Textiles, w earing apparel and leather products | 1 | 33 | 0 | 0 | 7 | 96 | 441 | 537 | 98 | 481 | 735 | | 1 557 |
| 12 Wood products, except furniture | 76 | 337 | 6 | 15 | 1 538 | 1 025 | 4 820 | 222 | 185 | 714 | 527 | | 5 941 |
| 13 Printing and paper products | 14 | 87 | 4 | 7 | 11 | 1 647 | 7 121 | 362 | 31 | 2 532 | 2 015 | | 10 046 |
| 14 Coke and refined petroleum products | 32 | 171 | 395 | 110 | 1 259 | 19 404 | 41 452 | 6 511 | -1 132 | 57 095 | 36 872 | | 103 926 |
| 15 Chemical and pharmaceutical products | 60 | 235 | 6 | 211 | 433 | 2 028 | 37 064 | 646 | 149 | 26 554 | 17 643 | | 64 413 |
| 16 Rubber and plastic products | 120 | 102 | 2 | 3 | 587 | 691 | 3 180 | 216 | 62 | 1 638 | 1 036 | | 5 096 |
| 17 Other non-metallic mineral products | 28 | 55 | 42 | 6 | 22 180 | 2 073 | 29 654 | 576 | 470 | 2 816 | 1 126 | | 33 516 |
| 18 Basic metals | 569 | 234 | 0 | 3 | 561 | 297 | 8 764 | 0 | 161 | 7 790 | 5 267 | | 16 715 |
| 19 Metal products, except machinery | 352 | 236 | 17 | 2 | 1 664 | 414 | 4 337 | 128 | 388 | 1 318 | 677 | | 6 171 |
| 20 Machinery and equipment | 269 | 171 | 1 | 2 | 429 | 417 | 2 412 | 359 | 2 384 | 3 499 | 4 300 | | 8 654 |
| 21 Transport equipment | 1 328 | 1 | 0 | 0 | 7 | 281 | 1 621 | 404 | 1 724 | 1 134 | 611 | | 4 883 |
| 22 Furniture and other manufactured goods | 18 | 90 | 18 | 2 | 58 | 1 253 | 1 623 | 1 014 | 644 | 521 | 524 | | 3 802 |
| 23 Total row 1–22 | 2 943 | 1 893 | 20 363 | 483 | 67 828 | 49 457 | 407 400 | 33 717 | 7 789 | 194 266 | 106 000 | | 643 172 |
| 24 Waste and recycled products | 0 | 22 | 1 950 | 25 733 | 24 015 | 0 | 144 670 | | 1 495 | 15 217 | 0 | 0 | 161 382 |
| 25 Extraction | 0 | 0 | 0 | 0 | 0 | 3 806 | 143 679 | | | | | | 143 679 |
| 26 Balancing item | 279 | 453 | 65 922 | 7 267 | 4 096 | 56 483 | 251 592 | 60 799 | 101 610 | | | 375 972 | 789 973 |
| 27 Total | 3 222 | 2 368 | 88 235 | 33 483 | 95 939 | 109 746 | 947 341 | 94 516 | 110 894 | 209 483 | 106 000 | 375 972 | 1 844 206 |

# Annex 3. Assets Accounts for Natural Gas

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|
| Opening stock | 1.865 | 1.997 | 1.836 | 1.572 | 1.390 | 1.304 | 1.230 | 1.130 |
| Reappraisal | 248 | - 45 | - 59 | - 62 | - 86 | - 74 | - 100 | - 86 |
| New discoveries of natural gas | 33 | 15 | 25 | 15 | 5 | 6 | 4 | 0 |
| Re-evaluation of discovered resources | 287 | 18 | - 17 | - 46 | - 5 | - 2 | - 25 | - 2 |
| Gross extraction | - 72 | - 78 | - 68 | - 73 | - 86 | - 79 | - 78 | - 84 |
| Underground storage of natural gas[1)] | - | - | 1 | 0 | 2 | 2 | 1 | 0 |
| Other adjustments | 0 | 0 | 0 | 42 | - 2 | - 2 | - 1 | 0 |
| Net closing stock | 2.113 | 1.952 | 1.777 | 1.510 | 1.304 | 1.230 | 1.130 | 1.044 |

[1)] In 1997 natural gas has been injected in one of the underground storage facilities for the first time.

Units: billion $Sm^3$

Sources: TNO / Ministry of Economic Affairs, 1988 – 2014 and Statistics Netherlands (2013);

http://statline.cbs.nl ‘Natural gas and oil reserves on the Dutch territory’

# Annex 4. Modelling Methods

The MFM and its, in this paper discussed, extensions in the MFM+ is a macro-economic accounting structure which means that it can take advantage of many of the macro-economic modelling options that are available. Here we list a few.

*Indicators*

The building blocks of the MFM+ provide a great variety of indicators that provides useful insights for policy makers. Tracking these indicators over time or comparing them between industries and countries helps to provide useful information about developments of all types of indicators.

- Absolute material flows
- Efficiency/productivity
- Elasticity
- Rates (of recycling, reuse, virgin material etc)
- Footprints
- Economic significance

*Regression/Time series analysis*

The relationships between the various indicators of the MFM+ can be analysed using a regression or time series analysis. However, for a regression analysis to be significant a large degree of variation in the data is required. This could be in various dimensions (time series, industries or countries). See for example Wiedmann et al (2014) which analyses the driving forces of material flows using multivariate regression.

*Input-output modelling*

Input-output modelling is based on the Leontief model which is based on the interconnectedness of industries in the economy. There are various variations of input-output modelling: Structural Path Analysis (SPA), Structural Decomposition Analysis (SDA), Key Sector analysis, Multiplier/Attribution/Footprint and Impact analysis (See Miller and Blair 2009; and Hoekstra 2010 for an overview of more than 500 environmental input-output applications)

*Scenarios, Partial/General Equilibrium Modelling*

All types of models can be built to analyse the impact of policies, technological changes or other changes. The reports of the Ellen McArthur foundation use a kind of 'what-if' scenario to estimate the savings that would be made if Europe transformed into a circular economy. More complex models, such as Partial or General Equilibrium Models are superior to input-output models because they are capable of analysing the effects of prices as well as other changes in the economy.

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# Explanation of symbols

| | |
|---|---|
| Empty cell | Figure not applicable |
| . | Figure is unknown, insufficiently reliable or confidential |
| * | Provisional figure |
| ** | Revised provisional figure |
| 2014–2015 | 2014 to 2015 inclusive |
| 2014/2015 | Average for 2014 to 2015 inclusive |
| 2014/’15 | Crop year, financial year, school year, etc., beginning in 2014 and ending in 2015 |
| 2012/’13–2014/’15 | Crop year, financial year, etc., 2012/’13 to 2014/’15 inclusive |

Due to rounding, some totals may not correspond to the sum of the separate figures.

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